APPENDIX F

RISK AND IMPACTS CONCEPTUAL MODEL

APPENDIX F

Risk and Impacts Conceptual Model Abstract

The objective of this discussion is to describe the Risk and Impacts conceptual model that has been developed for use in the System Assessment Capability, Revision 0 (SAC [Rev 0]). The general locations to be assessed for the Risk and Impacts technical element were identified based on regions where resources and their uses were identified as possibly “at risk” due to Hanford-derived contaminants. These locations include the Columbia River, from Priest Rapids Dam (including the Hanford Reach) to McNary Dam, and associated riparian zone. In addition, there will be a limited assessment of the upland areas of the Hanford Site.

The Risk and Impacts technical element will provide an assessment of the potential risks to human health and the environment, as well as potential impacts to the economic and socio-cultural resources of the Hanford Site and the surrounding environs. In addition, the assessment will allow feasibility testing of SAC (Rev 0). This technical element relies on input from each of the other technical elements in the SAC, depending on the scenario being evaluated (Figure F-i). Specifically, the other technical elements will provide spatial and temporal distributions of contaminant concentrations in the media (e.g., groundwater, surface water, soil, and sediment) to be used in the assessment.

The risk conceptual model has been broken into four components for SAC (Rev. 0). These include: 1) ecological risks and impacts; 2) human health risks and impacts; 3) economic risks and impacts; and 4) socio-cultural risks and impacts.

The SAC (Rev. 0) Risk and Impacts technical element will take the results of the analyses from the other technical elements and evaluate the following:

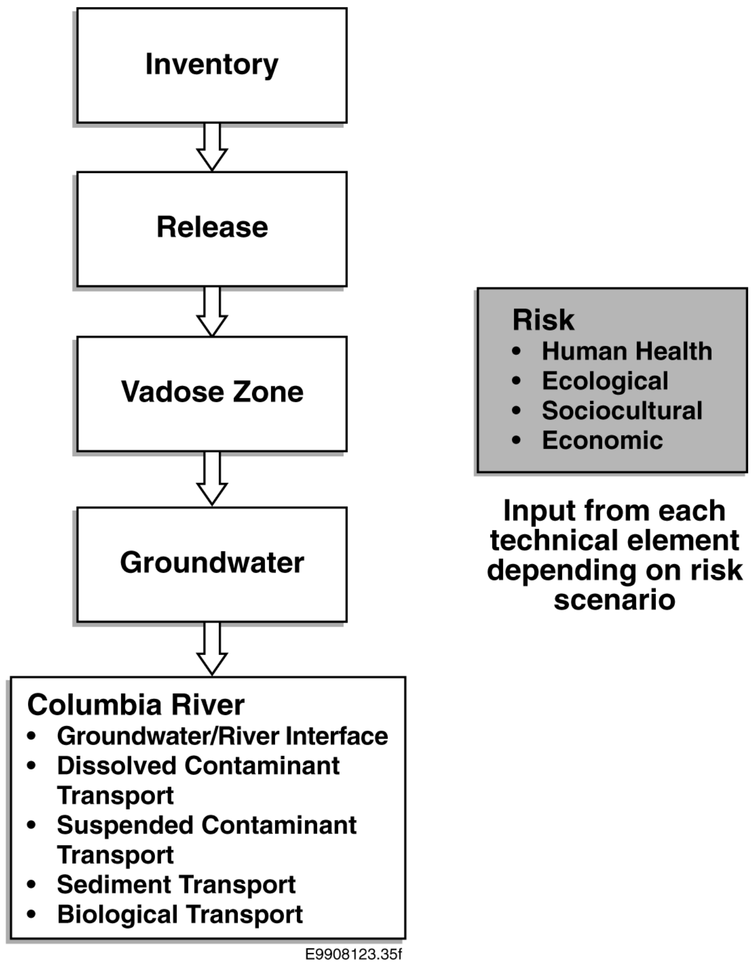
- Human health impacts: risk of cancer and of systemic or noncancer effects (e.g., respiratory or cardiovascular impacts).
- Ecological impacts: risk of exceeding lowest observable adverse effects levels for key individual species, and effects on the food web or ecosystem structure and function.
- Economic impacts: potential for public avoidance of products, avoidance of recreational activities, alternative water supply costs, and loss of business recruiting options
- Socio-cultural impacts: potential direct effects of contamination on resources of socio-cultural importance, and indirect effects of contamination resulting from human health, ecological, or economic impacts.

Specific data requirements for conducting the risk assessment and impact predictions are discussed in the body of the report.

Risks and Impacts Conceptual Model Abstract

The output from the Risk and Impacts technical element will be used in a risk characterization report. Risk characterization is the process of putting all the information gained from assessing risks and predicting impacts into context to “tell the story” for decision-makers and interested parties. The narrative, or story, includes a description of the contaminants, where the contaminants are located, how the contaminants are likely to move in the environment, and who or what may possibly be adversely affected. The descriptions of uncertainties in all the components of the assessment, and their effects on the results, are an important part of the risk characterization report.

Figure F-i. System Assessment Capability System Conceptual Model.



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RISK AND IMPACTS CONCEPTUAL MODEL

F.1 BACKGROUND

The System Assessment Capability (SAC) includes a risk technical element to assess risks and predict impacts. An impact is defined as an adverse effect or change, while risk is defined as the probability of an adverse effect.

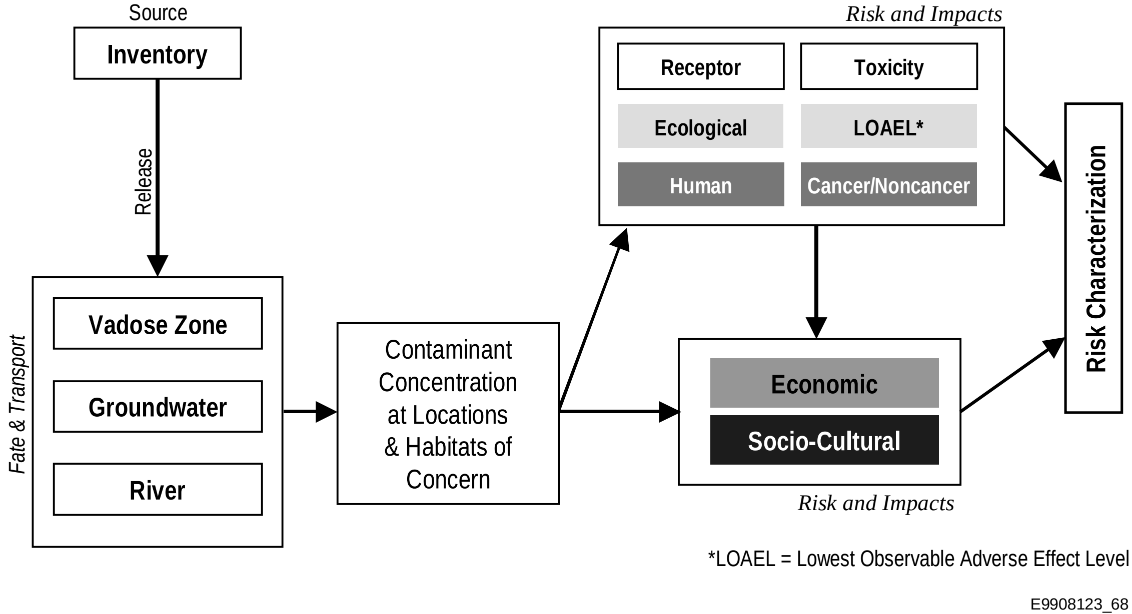
In 1998, the *Columbia River Comprehensive Impact Assessment* (CRCIA) (DOE 1998a) was published. Part I of the document presented a human health and ecological assessment of the near-river environs of the Hanford Reach and the McNary pool. In Part II of the assessment, the CRCIA team that helped direct the project presented their requirements for a comprehensive assessment that went beyond the human health and ecological assessment done in Part I. To the team, a comprehensive assessment includes addressing economic, social and cultural impacts, as well as human health and ecological impacts.

The Groundwater/Vadose Zone Integration Project agreed to conduct an assessment using the CRCIA Part II requirements as a template. The purpose of the risk assessment for the project is to determine potential risk to the environment, human health, economic, and socio-cultural quality of life from all contaminants of potential concern (COPC). The COPC are radionuclides and chemicals associated with Hanford activities, including research, since its inception and remaining after waste disposition is complete. The areas potentially affected by contamination include the Hanford Site groundwater, the Columbia River and its uses from the Hanford Reach downstream to the mouth of the Columbia River and along the coast from the Straits of Juan de Fuca to southern Oregon.

A potential health risk may result from the likelihood of an exposure to COPC and the likelihood of a toxicological response at a given exposure concentration. Human health and ecological risk assessment conceptual models typically identify 1) the source(s) of contamination (including type and location), 2) release mechanisms, 3) transport pathways, 4) potential routes of exposure and receptors, and 5) a toxicity evaluation. The information is then used to describe or characterize the risk. Impacts to social systems, cultures, and economies can result from substantial human health and ecological risks, but may also occur due to factors that are only indirectly tied to risks. The presence of contamination above background levels, regardless of the concentration, may affect access to resources and thereby cause changes in economic, social and cultural behaviors.

A generalized conceptual model for assessing risks and predicting impacts is illustrated in Figure F-1. The conceptual models from other SAC modules (inventory, vadose zone, groundwater, and river components) describe the inputs for this risk and impacts model. Routes of exposure and receptors are determined based on reasonable or representative human activities and ecological resources for the given location or area.

Figure F-1. Generalized Conceptual Model for Assessing Risks and Predicting Impacts.



Ecological and human health risk include both an exposure and a toxicity component. They rely on knowing the locations of COPCs in the environment. The location for COPC in the environment is defined by: 1) what is transported through the groundwater to the Columbia River; 2) the resultant COPC distribution in the river; and 3) groundwater use for the upland resident. Human health risk also considers exposure scenarios where people significantly alter the environment (drilling wells), such that it is possible for them to be exposed to COPCs. Exposures to ecological receptors are determined in large part by the characteristics of the locations of COPC and what species are located there. Toxicity is specific to a particular contaminant and depends on the receptor (human, nonhuman species) and the mode of exposure (e.g., ingestion, inhalation, dermal contact).

The economic and socio-cultural conceptual models build upon the conceptual models for ecological and human health risk. It is the goal of the economic impact assessment to develop monetary estimates of the impact from physical effects and from actions taken by the public to avoid risks of concern. The economic conceptual model is intended to complement the socio-cultural conceptual model, so that the combined scope of these models provides relatively comprehensive coverage of impacts to social and economic systems.

The socio-cultural risk assessment reflects a growing recognition that the conventional risk assessment paradigm does not address all the things that are "at risk". Communities may experience adverse effects in the health of their social and cultural systems, in addition to the more easily recognized human health and ecological impacts. The objective of the socio-cultural risk assessment is to determine whether the quality of life of the community (community health) is impacted.

Risk characterization is the process of putting all the information gained from assessing risks and predicting impacts into context to "tell the story" for decision-makers and interested parties. The narrative or story includes a description of the contaminants, where they are located, how they are likely to move in the environment and who and/or what may possibly be adversely affected. The descriptions of uncertainties in all components of the assessment and their effects on the results are a large part of the characterization of risks.

The general conceptual model should hold true for any SAC risk assessment; however, the scenarios included in different versions of SAC will vary. The risk technical element for SAC (Rev. 0) is a balance between the concerns of stakeholders and what risk metrics are available to use in the near term. Therefore, conceptual models for each component of the risk element (ecological, human health, economic, and socio-cultural) have been developed. Integration of the four components in the risk technical element's conceptual model is underway. This should result in diagrams that illustrate relationships between the components. The risk task for SAC (Rev. 0) will test new metrics designed for evaluation of socio-cultural quality of life and integration of the four risk components with each other, as well as integration with the other SAC technical elements.

This appendix presents information that forms the basis for the risk and impacts conceptual model, along with recommendations for the first iteration of the SAC (Rev. 0). The appendix is organized as follows. Section F.2 discusses relevant past projects that assessed risks and predicted impacts at the Hanford Site. Specifics on the ecological, human health, economic, and socio-cultural conceptual models are covered in Section F.3. Section F.4 summarizes how uncertainty will be addressed in the risk assessment and impact predictions. Section F.5 addresses the overall assumptions and technical rationale for the conceptual model. Section F.6 summarizes what the risk and impacts conceptual model is designed to analyze. In contrast, Section F.7 summarizes what the risk and impacts conceptual model is **not** designed to analyze. Outstanding risk issues are summarized in Section F.8. The path forward for the SAC (Rev. 0) risk assessment, along with impact predictions and proposed metrics, are discussed in Section F.9.

F.2 PAST PROJECT/EXISTING RISK AND IMPACT CONCEPTUAL MODELS

Numerous projects at the Hanford Site and surrounding areas that have assessed risks and predicted impacts are applicable to the conceptual models in this report. These projects have been completed to meet *Hanford Federal Facility Agreement and Consent Order* (*Tri-Party Agreement*) milestones, and are included in the analysis of alternatives for National Environmental Policy Act of 1969 (NEPA) environmental impact statements (EISs). Other analyses are also included that were used for decision-making purposes. Table F-1 illustrates the type of risk and impact conceptual models considered in these assessments. This section discusses the past projects and existing assessment conceptual models that form the basis for the ecological, human health, economic, and socio-cultural conceptual models discussed in Section F.3.

Table F-1. Risk Assessments and Impact Predictions at the Hanford Site.

Projects	**Ecological Assessments**	**Human Health Assessments**	**Economic Assessments**	**Socio-Cultural Assessments**
Tri-Party Agreement Milestone Projects	X	X		
NEPA EISs	X	X	X	X
Other	X	X	X	X

F.2.1 *Hanford Federal Facility Agreement and Consent Order*

Tri-Party Agreement projects (Ecology et al. 1998) have assessed risks and predicted impacts to support the Hanford Site cleanup mission. The primary federal statutes for risk assessments include the *Comprehensive Environmental Response, and Liability Act of 1980* (CERCLA) and the *Resource Conservation and Recovery Act of 1976* (RCRA). The primary state statutes for risk assessments include the Model Toxics Control Act (MTCA) and the *Hazardous Waste Management Act* (DOE 1995a). The *Hanford Site Risk Assessment Methodology* (HSRAM) was developed to provide consistent methods for conducting human health and ecological risk assessments for *Tri-Party Agreement* projects. HSRAM does not include any methodologies for economic and socio-cultural assessments.

Applications of risk-assessment techniques for the Hanford Site cleanup mission are covered in the *Hanford Past-Practice Strategy* (HPPS) (DOE 1992). The objective of HPPS is to expedite cleanup by initiating and completing waste-site cleanup through interim cleanup actions. Two types of assessments are indicated in HPPS: baseline risk assessments, and qualitative risk assessments. Baseline risk assessments have been conducted for cleanup actions that *were not* identified for interim action (for example, in the 300 Area). Risks have been qualitatively assessed for cleanup actions that were identified for interim cleanup actions (for example, in the 100 Areas).

The baseline risk assessments and qualitative risk assessments for the Hanford Site have included toxicological evaluations of human health. The endpoints were incremental lifetime cancer risks for the carcinogenic chemicals and radionuclides, and hazard indexes for the noncarcinogenic chemicals. Ecological impacts were also evaluated in each type of assessment for selected organisms. The ecological endpoints were calculations of total daily doses from radionuclides for comparison to the U.S. Department of Energy (DOE) benchmark of 1 rad/day, and comparison of the maximum representative nonradioactive contaminants to the acute or chronic lowest observable effect levels (DOE 1995a).

Other *Tri-Party Agreement* projects have used HSRAM to perform human health and ecological assessments. These are discussed further in Section 2.3.

F.2.2 National Environmental Policy Act Environmental Impact Statements

NEPA requires consideration of potential environmental impacts associated with federal agency actions, and provides opportunities for public involvement in the decision-making process. EISs are organized into sections describing the affected environment and evaluating the environmental consequences of the potential impacts associated with the actions being considered. Environmental systems, human health, cultural resources, and economics are described and evaluated in EISs. Numerous EISs have been prepared for the Hanford Site and its associated programs, projects, and facilities.

F.2.3 Various Conceptual Models Associated with Ecological, Human Health, Economics, and Socio-Cultural Impacts

This section discusses conceptual models with specific applications to ecology, human health, economics, and socio-cultural impacts.

F.2.3.1 Ecological Risk Assessment Conceptual Models. This section describes the ecological risk assessments have been performed at the Hanford Site. Most of the Hanford projects that include ecological risk assessments are directed at how to evaluate risk from COPCs by specific regulations and their associated guidance. Several EISs have been prepared following NEPA guidance. The U.S. Environmental Protection Agency (EPA) standards and guidelines for ecological risk assessments include the Ambient Water Quality Criteria methodology, the Ecological Risk Assessment Framework, and recently, the Guidelines Ecological Risk Assessment. While MTCA currently does not include ecological risk assessments, requirements and methodologies are being drafted for incorporation.

HSRAM provides guidelines and methodology for Hanford Site-specific ecological evaluations. The guidelines and methodology are consistent with EPA's framework for ecological risk assessment. HSRAM has been used for almost all of the assessments performed under the *Tri-Party Agreement*.

A variety of ecological assessments have been performed under the *Tri-Party Agreement*, including a CERCLA baseline risk assessment for the 300-FF-5 Groundwater Operational Unit and the qualitative risk assessment for the 100-HR-3 Groundwater Operational Unit. Both of these assessments used groundwater monitoring data to evaluate risk from COPCs to aquatic life in the Columbia River. In addition, some vegetation and small mammals were collected and analyzed for uptake of metals and radionuclides in the 100 (Weiss and Mitchell 1992) and 300 Areas (WHC 1993).

F.2.3.1.1 Qualitative Risk Assessment for the 100-HR-3 Groundwater Operable Unit (WHC 1994). The ecological evaluations for the qualitative risk assessments (QRA) were an abbreviated version of the EPA's Framework (EPA 1992) that was agreed upon by the *Tri-Party Agreement*. The number of biological receptors and the number of exposure routes to each receptor were limited to fewer than would be considered in a typical baseline risk assessment. The 100-HR-3 QRA analyzed the potential effects associated with discharge of groundwater of selected receptors associated with the Columbia River.

The conceptual model for the QRA considered contaminants transport from the groundwater to springs into the Columbia River. Uptake and transport of contaminants into the aquatic foodweb was assumed to be by algae and other first order producers. Exposure was considered from both foodchain uptake and direct exposure in the river. Aquatic plants, fish, crustaceans, ducks and heron were the potentially-affected organisms in the assessment.

In the QRA, measurement endpoints were for aquatic and riparian organisms. For radionuclides, the measurement endpoint was total organism dose, and was compared to the 1 rad/day benchmark (DOE 1993a). For the COPC other than radionuclides, the dose/response relationship was based upon the lowest observable effects levels (LOEL) as a threshold, and if the chemical exceeded the LOEL, then it was assumed that some component of the ecosystem will be affected. The QRA concluded that the chromium and sulfide levels in near-river wells were above the LOEL and a potential concern to juvenile chinook and trout in the Columbia River.

F.2.3.1.2 Columbia River Comprehensive Impact Assessment (DOE 1998a). CRCIA, Part 1, is the most current conceptual model for analyzing impacts of COPCs from Hanford on the Columbia River. This assessment was a screening-level ecological risk assessment of the Columbia River ecosystem in the Hanford Reach and McNary reservoir. The assessment in the CRCIA went beyond the approach recommended in HSRAM and included recent advances in evaluating ecological effects through a food web.

The ecological species evaluated included 53 species of aquatic and terrestrial plants, aquatic invertebrates, amphibians, reptiles, fish, birds, and mammals. It estimated potential risk to individual organisms by assessing body burden or dose from ingestion, inhalation, and dermal exposure to COPCs and comparing it with toxicity information. COPCs were those detected between 1990 through 1996 within a ¼-mile range of the Columbia River. The species were selected based on their significance to Native American cultures, ecological importance, whether they were native to the study area, and the availability of toxicological data (Becker et al. 1998).

The food web approach for ecological risk assessment in the CRCIA included species that are consumed by humans. The dose for these species was then used in the human health assessment.

As mentioned above, NEPA evaluates the affected environment. Two relevant documents are the Hanford Reach EIS and the Hanford Remedial Action-EIS. These are good resources for information on the Columbia River environment near Hanford. The connection between exposure to COPCs and effects, however, is limited.

F.2.3.2 Human Health Risk Assessment Conceptual Models. The conceptual model for Human Health risk will use the same scenario as presented in Table F-2. The selected scenario for the SAC (Rev. 0) are listed and described in Section F.3.2 of this appendix.

Table F-2. Risk Assessment Lifestyle Scenarios.

Guidance		Human Health Exposure Scenarios					
Standard		Residential	Industrial	Recreational	Agricultural	Rural-Residential	Native American
EPA RAGS		X	X				
MTCA		X	X	X			
HSRAM		X	X	X	X	X[a]	
CRCIA		X[b]	X[c]	X[d]	X[e]		X[f]
NEPA	HRA	X	X	X	X		
	TWRS	X[g]	X	X			X[h]
Others	RPE	X[g]	X	X			X[h]
	HEDR	X					
	PA	X					
	CA	X[i]	X[i]	X[i]	X[i]		

[a] Rural-residential was negotiated and agreed to by Ecology, EPA and DOE-RL based on EPA and MTCA standards and guidance.
[b] Under CRCIA, based on factors used in HSRAM. Modified to use Columbia River water versus groundwater
[c] Under CRCIA, this scenario is similar to the industrial/commercial worker for HSRAM. It took into account exposure from contact with environmental media versus substances encountered as part of the job.
[d] Under CRCIA, this scenario is considered a wildlife Refuge/Wild and Scenic River scenario. It assumes that human exposure such as ranger, hunter/fisher, and other general recreational users would have to be assessed for risk.
[e] Under CRCIA, this scenario considers the range of potential Native American activities, including subsistence resident, hunter/gatherer, cultural activities visitor, and Columbia River Island user.
[f] Draft interim regulatory guidance, "Hanford Guidance for Radiological Cleanup."
[g] Represents residential farmers and includes agricultural production.
[h] This scenario assumes both traditional and contemporary lifestyle activities, such as hunting, fishing, using a sweat lodge, and irrigated farming.)
[i] The results were reported in dose.

F.2.3.2.1 Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit (DOE 1993b). The Phase I remedial investigation report for the 300-FF-1 operable unit includes a baseline risk assessment. The report identified three potential receptor populations: onsite industrial, offsite residential, and offsite recreational. These are similar to the HSRAM scenarios. The identification of exposure pathways used to evaluate industrial, residential, and recreational scenarios was based on HSRAM (DOE 1995a). Because the 300-FF-1 operable unit was focused only on soils, no groundwater or surface water pathways were evaluated. The primary exposure pathways for the industrial scenario were inhalation of fugitive dust, inhalation of volatile organics, soil ingestion, dermal exposure, and external exposure. The residential scenario used inhalation of fugitive dust and inhalation of volatile pathways. The recreational scenario used ingestion of game birds in addition to inhalation of fugitive dust and volatile organics.

Human health toxicity was assessed in accordance with RAGS (EPA 1989a), and with the discussion in HSRAM (DOE 1995a). In general, risk and toxicity were assessed in two stages: identifying hazards and evaluating dose responses. Hazard identification (or identification of COPC) determined whether exposure to an agent would result in an adverse health effect. Dose-response evaluation quantitatively characterizes the relationship between the dose of a toxic substance and the corresponding likelihood of deleterious effects in an exposed population (EPA 1989b).

F.2.3.2.2 Qualitative Risk Assessment for the 100-HR-3 Groundwater Operable Unit (WHC 1994). The 100-HR-3 QRA identified two potential receptor populations: frequent-use scenario (e.g., residential) and occasional-use scenario (e.g., recreational). These scenarios were based on an early revision of HSRAM (DOE 1993a). They provided "upperbound and reasonable maximum exposure estimates of risk". Another scenario was qualitatively evaluated, which considered the occasional use of springs along the Columbia River as a source of drinking water. Because the assessment was for a groundwater operable unit that was adjacent to the Columbia River, the focus of the assessment was on groundwater and surface water. The exposure pathways were ingestion of groundwater, inhalation of volatile contaminants during water use (for the frequent-use scenario only), and external exposure from radionuclides.

The human health toxicity assessment for 100-HR-3 were based on RAGS (EPA 1989b) and an early revision of HSRAM (DOE 1993a). Since the assessment was qualitative, the toxicity assessment included sufficient information on the COPC to assist decisions on interim remedial measures and did not include an evaluation of all potential toxicities.

F.2.3.2.3 Hanford Remedial Action (HRA) EIS and Comprehensive Land Use Plan (DOE 1999b). The human health risk analysis in the HRA EIS was designed to compare the environmental impacts of proposed major federal actions that might significantly affect the quality of the human environment. This EIS evaluated several scenarios, including the agricultural, residential, industrial, and recreational scenarios. The exposure scenarios were modeled after those in the HSRAM. Each of the scenarios was evaluated for five transport media: surface and subsurface soil, groundwater, surface water, and air. The HRA EIS was the first Hanford project to present human health risk spatially and temporally. The resultant risk was presented graphically, using contours that represented the boundary of the risk values. The end point for the human health impact was lifetime cancer risk for the carcinogenic chemical and radionuclides, and hazard index for the noncarcinogenic chemicals.

F.2.3.2.4 Tank Waste Remediation System (TWRS) EIS (DOE 1996a). The long-term risk analysis in the TWRS EIS was designed to compare impacts of each alternative to a potential future population (Native American, residential farmer, industrial worker, and recreational land and shoreline user), given hypothetical future land uses. The short-term risk from remedial activity and operation was analyzed for the onsite worker (involved and noninvolved), and offsite maximum and average member of the public. The intruder scenario for a settler who drills a well (by a commercial drilling company) through the contaminated area (tank and vadose zone) was analyzed. The long-term cumulative analysis evaluated human health impacts to the anticipated population of the Columbia River user from the Hanford Reach all the way to the Pacific Ocean for 10,000 years into the future.

The long-term risk evaluated several scenarios, including the Native American Scenario, the residential farmer, the industrial worker, and recreational land and shoreline user. These scenarios and parameters were consistent with EPA and HSRAM guidance. The residential farmer was a combination of residential and agricultural scenarios. The Native American scenario was based on the residential farmer, with some additional Native American specific pathways (e.g., fish consumption, sweat lodge, and shoreline activities). The TWRS EIS presented the long-term risk spatially and temporally in the same manner as the HRA EIS.

The short-term risk from routine operation was based on the direct exposure and atmospheric transport pathways (no groundwater pathway). The onsite involved-worker primary pathway was direct exposure; the onsite noninvolved-worker pathway was via atmospheric transport. The offsite population (maximum and average) transport media was air, and the pathway included inhalation, ingestion, and dermal. The intruder scenario was from Nuclear Regulatory Agency guidance that represents an individual who lived on the land that was uniformly contaminated with the exhumed waste from drilling operation. The soil before drilling was assumed to be clean, with no contamination in the groundwater. The scenario only analyzed the effect of exhumed contaminants. The drilling was performed by a commercial drilling company. The individual driller was exposed by direct contact with exhumed waste, and inhalation of suspended particulate during the drilling operation (total of 40 hours).

The Columbia River user risk was assessed for down river population (incremental increase in population as time increased) for 10,000 years into the future. The scenario was the same as the residential farmer who used the Columbia River for all their water needs, such as drinking, showering, and irrigating crops.

The end point for the human health impact was lifetime cancer risk for the carcinogenic chemical and radionuclides, and hazard index for the noncarcinogenic chemicals.

F.2.3.2.5 Columbia River Comprehensive Impact Assessment (DOE 1998a). *Tri-Party Agreement* Milestone M-15-80 was established in 1995 and is the regulatory driver for the CRCIA report. The scenarios for the human health assessment were designed to illustrate the range of activities possible by members of the public coming in contact with the Columbia River. The scenarios developed include the following:

- Industrial/Commercial scenarios, including industrial worker and fish hatchery worker
- Wildlife Refuge/Wild and Scenic River scenarios, including ranger, hunter/fisher, and recreational visitor
- Native American scenarios, including subsistence resident, hunter/gatherer, cultural activities visitor, and Columbia River island user
- General Population scenarios, including residential and agricultural.

The industrial/commercial scenario is broken into two distinct scenarios: Industrial/Commercial Worker, and Fish Hatchery Worker. The Industrial/Commercial Worker scenario is a standard scenario based on the HSRAM, and focuses on worker exposure to residual environmental contamination. The Fish Hatchery Worker was developed based on the current use of 100-K Area facilities in development of the commercial aquaculture program. This scenario has a greater exposure frequency and duration than the standard industrial/commercial worker scenario.

The Wildlife Refuge/Wild and Scenic River scenarios basically comprise of a recreational scenario, evaluating exposure from activities such as backpacking, bird watching, camping, picnicking, river boat touring, swimming, water skiing, and wildlife viewing. The scenario is similar to that provided by the HSRAM, but it is broken into three separate components. It has a Ranger scenario, which represents an individual visiting most habitat types on the site on a regular basis. The Ranger scenario is similar to the HSRAM Industrial scenario, except that more time is spent onsite. The Hunter/Fisher scenario is based on an individual visiting the site frequently to fish and hunt.

The Native American scenario covers a broad range of activities related to traditional and contemporary lifestyle. Some of the activities have no standard suburban surrogate activity in HSRAM. This scenario is broken into four separate components, and covers subsistence resident, hunter/gatherer, cultural activities visitor, and Columbia River Island user. The subsistence resident scenario represents a reasonable set of activities that reflect traditional lifestyle activities occurring for life on the Hanford Site. The scenario is based on tribal information, and assumes access to both the shoreline and to seeps/springs.

The hunter/gatherer and cultural activities visitor scenario basically splits the subsistence resident into two sets of lesser activity for exposure duration. It also assumes that there would be no groundwater access except via biotic uptake. The Columbia River Island user scenario is based on Native American traditional uses of the islands within the Columbia River. Standard exposure parameter values for this scenario are provided by HSRAM for uptake of soil onto skin (dermal).

The general population scenario includes a residential scenario and an agricultural resident scenario. They are similar to those in HSRAM, except with respect to irrigation. To accommodate potential irrigation with river water for the resident and agricultural scenarios, irrigation of fruits and vegetables is included at a rate of 45 inches per year. No groundwater pathways are included in applications off the Hanford Site.

The end point for the human health impacts was lifetime cancer risk for the carcinogenic chemical and radionuclides, and hazard index for the noncarcinogenic chemicals.

F.2.3.2.6 Retrieval Performance Evaluation (DOE 1999a). RPE methodology for the AX tank farm examined an approach for retrieving the liquid tank waste in the 200 Areas. The purpose of the analysis was to evaluate the effectiveness of liquid retrieval from the single-shell tanks in reducing potential risk as part of the TWRS project. The report assessed and presented long-term human health impacts for the future land use in the same manner as the TWRS EIS. The time interval was selected differently than those used for the TWRS EIS. The short-term (involved and noninvolved worker) risk was based on the TWRS EIS methodology, with the same scenarios and receptors.

A complete stochastic analysis was performed for this report to evaluate the sensitive parameters, based on the uncertainty of the parameters and system. The residential farmer scenario (and its associated parameters) were selected, among the five long-term scenarios, for the stochastic analyses. The risk result was used to measure and evaluate the sensitivity of the system parameters (source, source-term, vadose zone, groundwater, and exposure) via regression analysis.

The end point for the deterministic human health impacts was calculated and reported as incremental lifetime cancer risk for carcinogenic chemical and radionuclide, and hazard index for the noncarcinogenic chemicals.

F.2.3.2.7 Hanford Environmental Dose Reconstruction Project (HEDR). The HEDR Project was initiated as a result of public interest in the historical releases of radioactive materials from the Hanford Site. In early 1986, an 18 member independent technical steering panel (TSP) was formed to direct the work. The scope of work included search for and retrieval of historical operations and monitoring information, and demographic, agricultural, and lifestyle information necessary to: 1) reconstruct source terms; 2) model environmental transport in the atmosphere and the Columbia River; 3) model transport and accumulation of radioactive materials in environmental media and food products; 4) determine food consumption and lifestyle patterns; and 5) estimate doses to real and representative individuals who may have lived in the vicinity of the Hanford Site during its operation. The project used a set of source term, transport, environmental accumulation, and dose models that were intimately linked, allowing transfer of information in such a way that spatial, temporal, and distributional characteristics of the data were preserved.

Scoping studies indicated that the primary radionuclide of interest from the atmospheric pathway was iodine-131 (released from the chemical separation plants) (Farris et al. 1994a). The estimated total release of iodine-131 from Hanford Site operations is 730,000 curies. Additional radionuclides addressed in detail include ruthenium-103, ruthenium-106, strontium-90, cerium-144, and plutonium-239. Uncertainties in the actual amounts released were addressed through use of multiple Monte Carlo simulations, each of which represents an alternative release history that is consistent with existing knowledge.

The Columbia River, which passes through the Hanford Site, was the source of cooling water for the original plutonium production reactors (Farris et al. 1994b). The river water was drawn directly through the reactor core, and returned to the river after a short retention time. The Columbia River is the major pathway for water-borne radionuclides. Scoping studies indicated that the radionuclides of greatest interest to the HEDR Project are zinc-65, phosphorus-32, sodium-24, neptunium-239, and arsenic-76. These radionuclides provide about 94% of radiation doses to people using the river.

The model used for analysis of transport of radionuclides in the Columbia River is called CHARIMA. The CHARIMA code is a commercial surface water hydrology and sediment transport model. It uses daily river discharge and water surface elevation data to predict dilution and travel time to downstream locations. The model is basically one-dimensional, but the HEDR Project added empirical corrections for lateral dispersion at some locations near reactor outfalls (Farris et al. 1994b).

The terrestrial environmental accumulation model, DESCARTES, tracks and estimates the accumulation and transfer of radionuclides from initial atmospheric deposition and interception through various soil, vegetation, and animal products compartments. This model contains a set of coupled linear differential equations that give the model its dynamic nature, generating daily soil and vegetation concentrations. Other portions of the model use these daily concentration data and equilibrium-type equations to estimate time-dependent radionuclide concentrations in animal products (Farris et al. 1994a).

The commercial milk distribution systems were reconstructed from records and reports available from the U.S. Bureau of Census, the Washington State Dairy Herd Improvement Association, the Washington State Dairy Products Commission, and other governmental and dairy industry organizations that are supplemented and organized by local experts into a detailed source/distribution network by project domain grid cell. A similar undertaking was needed for the distribution system for fresh leafy vegetables (Farris et al. 1994a).

Extensive environmental monitoring was performed on aquatic organisms in the Columbia River during the latter years of Hanford Site operations. Many thousands of river water and fish samples were collected. The HEDR project cataloged this information and used it to develop season- and species-dependent bioconcentration factors, which were used to estimate radionuclide concentrations in river and ocean biota (Farris et al. 1994b).

The primary thrust of the HEDR modeling effort was to prepare a complete system through which individuals could receive estimates of their dose from past Hanford Site operations. The terrestrial dose model, CIDER, calculates dose for four pathways: submersion in contaminated air; inhalation of contaminated air, irradiation from contaminated surfaces; and ingestion of contaminated farm products and vegetation. The CIDER code treats people differently as they age, including prenatal and nursing periods. The Columbia River Dosimetry (CRD) model calculates dose via water immersion, drinking, and consumption of resident fish, game birds, salmon, and ocean shellfish (Farris et al. 1994b).

The HEDR Project included the concepts of uncertainty and sensitivity analysis from its inception. Uncertainty analyses were conducted for essentially all dose estimates. A Monte Carlo technique was used to estimate all dose uncertainties. Sensitivity analyses were performed for all HEDR models, providing a method for 1) effectively interpreting the dose estimates; and 2) prioritizing individual parameters according to the uncertainty they contribute to the estimated doses. For the complex set of HEDR models, the sensitivity analyses were done hierarchically, starting with the dose results and working backward through the various pathway, transport, and source term models (Farris et al. 1994a, 1994b).

F.2.3.2.8 Performance Assessments. A performance assessment (PA) is a detailed analysis of the long-term human health and environmental impacts from the disposal of low-level wastes (the term is sometimes used for other waste disposal such as the disposal of high-level waste at a geologic repository). The main regulatory driver for a performance assessment is the DOE Order on the management of radioactive waste (formerly DOE Order 5820.2A, and now DOE Order 435.1) that explicitly mandates their creation, review, approval, and (435.1) maintenance. This order enforces the requirement of the *Atomic Energy Act* to protect public health and safety.

Besides providing the regulatory basis for licensing the disposal activity, PAs must be used (by requirement of DOE Order 435.1) as the technical basis for setting waste-acceptance criteria, monitoring plans, and closure plans. A PA normally includes vadose zone, groundwater, and air media for the waste to be disposed of. The ILAW PA also considered Surface water (e.g., the Columbia River) was also considered in the *Hanford Immobilized Low-Activity Tank Waste-Performance Assessment*.

The DOE order on radioactive waste management requires that estimated performance be compared against "performance objectives." Such performance objectives are usually an all-pathways dose (25 mrem in a year) not more than 100 meters from the facility for a period of time (1,000 years in DOE O 435.1) and a surface flux of less than 20 pCi/m^{2}s (radon) or a dose of 10 mrem in a year for other atmospheric releases. In addition, water resources must be protected in compliance with federal, state, and local requirements. Such protection is usually expressed as a drinking water dose or as contaminant concentration. In addition, inadvertent intruder limits (500 mrem in a year for acute exposures and 100 mrem in a year for continuous exposures) are set. The following list presents some of the PAs performed at the Hanford Site.

- *Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste from N Reactor Operations*.
- *Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford*.
- *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds*.
- *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Waste Burial Grounds*.
- *Environmental Remediation Disposal Facility Performance Assessment*.
- *Hanford Immobilized Low-Activity Tank Waste-Performance Assessment*.

F.2.3.2.9 Composite Analysis (Kincaid et al. 1998). A radiological impacts analysis was recently completed for low-level waste disposal sites and other contaminant sources in the 200 Areas Plateau, which is a waste management area on the Hanford Site.

The objective of the analysis was to assess cumulative dose impacts to hypothetical future members of the public in an accessible environment postulated between the 200 Area Plateau and the Columbia River during the1000 years after projected site closure (2050). Estimating dose was a multi-step process involving 1) estimating radiological inventories and releases for 241 unique source sites to the environment, 2) assessing contaminant migration through the vadose zone, groundwater, and atmospheric pathways; and 3) estimating doses for scenarios based on agriculture, residential, industrial, and recreational land use. The radionuclides included in the vadose zone and groundwater pathway analyses of releases were carbon-14, chlorine-36, iodine-129, selenium-79, strontium-90, technetium-99, tritium, and uranium isotopes. Radionuclides considered in the atmospheric pathway included tritium and carbon-14.

The analysis showed that most of the radionuclide inventory in past-practice liquid discharge sites and the pre-1988 solid waste burial grounds on the 200 Areas Plateau would be released in the first several hundred years following Hanford Site closure. These releases are estimated to occur well before projected releases from active and planned disposals of solid waste, environmental restoration waste, and immobilized low-activity waste. The maximum predicted agricultural dose outside the 200-Area plateau was less than 6 millirem in a year in 2050, and declined thereafter. The maximum doses estimated for the residential, industrial, and recreational scenarios were 2.2, 0.7, and 0.04 millirem in a year, respectively, and also declined after 2050.

F.2.3.3 Economic Impact Risk Assessment Conceptual Models. This section describes several projects that have assessed economic impact for the Hanford Site and surrounding areas.

F.2.3.3.1 Surplus Plutonium Disposition EIS (DOE 1998b). This analysis assesses impacts of plutonium-disposition activities at two spatial scales. A nine-county regional economic area (REA) is used to estimate employment impacts. REAs are broad market areas defined by the U.S. Department of Commerce as discrete areas that capture economic linkages among industrial and service sectors and households. A smaller, two county (Benton and Franklin) region of influence (ROI) is used to assess impacts to population, housing, and local public services (including education, public safety, and health care). Forecasts of population and employment produced by the U.S. Department of Commerce are used to provide projections of REA and ROI baselines.

Construction and operating expenditures associated with each disposition alternative are used in association with regional input-output modeling system (RIMS II) multipliers that are developed by the U.S. Department of Commerce to produce estimates of employment impacts. Multipliers measure the extent to which direct expenditures lead to subsequent impacts in the region around the site. Multipliers take into account the level of interconnectedness between sectors where subsequent rounds of spending occur, and consequently the nature of the impact occurring. They also account for the extent to which the region as a whole is capable of absorbing spending on waste management activities at the site and, consequently, the magnitude of the overall economic impact.

Public service impacts are estimated based on an assessment of additional workforce requirements under each alternative, compared to the capacity of community service providers.

F.2.3.3.2 Waste Management Programmatic EIS (DOE 1997). This DOE complex-wide document measures the impacts on employment, disposable income, and output (sales) of the various Hanford waste management alternatives at the regional and national level (all facilities in the complex). At the regional level, impacts are measured in the five counties surrounding the site (Adams, Benton, Franklin, Grant, and Yakima), where 90% of site employees live (each county had at least 5% of the site workforce).

The analysis uses RIMS multipliers as the basis for modeling impacts of waste management activities. Construction and operating expenditures related to each alternative are used together with multipliers derived from RIMS to estimate the direct (onsite) and indirect (offsite) impacts of each activity in terms of disposable income, output (sales), and employment. Multipliers for 80 economic sectors, including households and government, were used to calculate impacts.

Demographic impacts were calculated for the site by assessing the percentage of workers required under each alternative that would be drawn from the local area. The potential impact of the remaining workers on the public service delivery system is then considered.

The impact of adverse public perceptions of waste management activities are recognized, in particular the impact on property values and business retention in the vicinity of proposed radioactive waste disposal facilities, but data limitations and programmatic scope considerations resulted in these impacts not being assessed.

F.2.3.3.3 Hanford Remedial Action EIS and Comprehensive Land Use Plan (DOE 1999b). Qualitative estimates of the impacts are developed for a variety of land-use scenarios on industrial development, research and development initiatives, agricultural activity (irrigated and dryland crops, grazing), mining, and recreational opportunities. The amount of land released from DOE control under each alternative is compared to forecasts of local land requirements made by the Benton County Planning Department for industrial and for research and development activities, given certain growth assumptions. The report then speculates on the amount of employment subsequently created on this land by these activities. Additional demands on local infrastructure created by development on land released by DOE (in the event that this development exceeds local forecasts are described).

Natural resources available for development with transfer of the land to public use are described. These include cattle grazing, irrigated and dryland agriculture, sand and gravel mining, and natural gas development. Increased recreational opportunities along the Columbia River with the release of additional waterfront for public use are described, with estimates of likely use rates and benefits to the local economy, together with additional opportunities for tourism through better access to preserved habitats and associated species.

F.2.3.3.4 Spent Nuclear Fuel from the K Basins (DOE 1995b). Employment and income impacts of a range of spent fuel management options are provided using the IMPLAN (IMPact Analysis for PLANning) regional economic model developed by the Minnesota IMPLAN Group. The analysis uses data for Benton and Franklin Counties. IMPLAN data are compared with data produced in other regional economic studies on the Hanford area that were produced using the RIMS model to establish consistency. Impacts on housing and local community infrastructure (education, health, human services, fire, police protection, and parks and recreation) are also provided, based on estimates of changes in local population under each alternative.

The analysis uses data on expenditures by onsite employees, and includes assumptions on the net impact of management activities on the overall Hanford workforce. Additional information on the value and type of procurements for subcontracts, materials, and services by the management contractor is used, together with limiting assumptions on the extent and nature of local procurement. These data are used as input to the IMPLAN model to provide estimates of impacts on local jobs and incomes. Changes in population, and consequently changes in community infrastructure, were based on the methodology used in the Spent Fuel Programmatic

EIS, where a population multiplier relating impacts to employment impacts was used. Although in-migration is assumed to occur under each alternative, there is no discussion of the methodology used in the analysis.

F.2.3.3.5 Plutonium Finishing Plant Stabilization (DOE 1996b). Two geographic areas are used in the document: 1) a study area including Benton and Franklin Counties; and 2) a region-of-interest, which includes the study area together with Yakima and Grant Counties. The analysis of impacts uses onsite expenditure data to assess the impacts of various alternatives on employment, output (sales) and place-of-work income in the study area using the IMPLAN model. Impacts on population, housing and community infrastructure are largely based on interviews with local public officials. Impacts of each of the alternatives are inferred from these interviews, rather than being based on quantitative analyses.

Unlike other impact assessments using IMPLAN or RIMS, the study classifies all expenditures associated with stabilization plant alternatives into the government sector of the IMPLAN model. Other studies break down expenditures into those local or nonlocal sectors, including households, in which expenditures actually take place. This method provides a more accurate means of assessing the extent and nature of local impacts than mapping all expenditures into one sector. While it may be possible to map expenditure changes in some industrial activities, such as steel making, into one specific sector, the government sector includes activity in any local, state, and federal government agencies based in the area where impacts are being assessed. With such a diverse range of activities, many of which are quite different to those occurring at the stabilization plant, the IMPLAN multipliers associated with the sector will not likely accurately portray the nature and size of impacts of the facility.

F.2.3.3.6 Tri-Cities Economic Impact Model. (Tri-Cities Economic Impact Model 1996; Weimar et al. 1997; DOE 1998c; DOE 1999c). The Tri-Cities Economic Impact Model was adapted from a version of the IMPLAN modeling system for Benton and Franklin Counties. IMPLAN is a regional economic modeling system, originally developed by the U.S. Forest Service, in cooperation with the Federal Emergency Management Agency. IMPLAN provides a framework for analyzing the economic impacts (changes in employment, output, income, etc.) from any number of economic shock scenarios. Examples include effects of public policy, new plant locations, tourism expenditures, plant closings, major events, or technology change. The heart of the IMPLAN system is the 538-sector benchmark input-output table for the US economy, which is maintained by the Bureau of Economic Analysis (BEA), an agency of the U.S. Department of Commerce. In developing the special-purpose version for the Tri-Cities, the researchers:

- Updated the national and regional model default coefficients to the BEA data released in 1994. These values have been price-updated to 1992 constant dollars. Updates were based on the following factors:
  - The most recent local estimates of employment and payroll available (1996-1998) from the U.S. Department of Commerce Regional Economic Information System and the State of Washington Department of Employment Security.

  - Data on retail sales from the Washington State Department of Revenue.

  - Data on population from the Washington State Office of Financial Management. These were used to re-calibrate the default model coefficients to local conditions as of 1996.

- Tested the model on 1998 conditions.

- Used the baseline final demand profile to benchmark the Tri Cities model to 1996 economic information for Benton and Franklin Counties (the most recent year with most complete data).

The model is designed to evaluate the effects of local economic activities on the estimated tax revenues generated for use by the county government. The model uses expenditure information to estimate the economic impacts of a given scenario and then uses the economic impacts to estimate county revenue effects. To estimate reliable results, several guidelines for developing impact scenarios must be observed.

Currently, the model is designed for “one-shock-at-a-time” analysis. This means that if the analyst wants to evaluate the impacts of several concurrent events/shocks/activities in the economy, each must be analyzed as an individual scenario, and the results across all of the scenarios must then be aggregated to estimate the net effect.

F.2.3.3.7 Yakima Valley Farm Production Model: An Agricultural Economic Model for Environmental Preservation (Scott et al. 1998a, 1998b; Jaksch et al. 1998). This project developed a computerized farm economic model to enable farmers to evaluate the costs and returns associated both with traditional crops and longer-rotation crops (e.g., hybrid poplars). The goal is to help farmers, or irrigation districts working with farmers, to evaluate where and under what conditions it would be economically feasible to plant specific crops and crop rotations (particularly hybrid poplars) as an alternative to other crops or crop rotations. The model has the capability of rapidly evaluating the price, yield, and cost sensitivity of results, and may be used to understand profit uncertainties for time periods up to 20 years. This is important in evaluating long-lived tree crops in comparison with shorter-lived annual crops or crop rotations. The farm model has an open architecture and is designed so that assumptions concerning farm operations can easily be changed. Thirty crops are currently available. The user has the option of accepting default values for components of cost, or overriding these values with costs that more accurately reflect his/her own operation. The user also has the choice of introducing entirely new crops or of combining up to four crops in a 20-year crop rotation cycle, which may then be saved or edited online. The user can accept default yields and market prices for crops contained in the model, or may substitute values based on his/her own experience.

The model automatically calculates annual profitability and the 20-year discounted cash flow over 20 years for any crop or crop rotation available in the model. The model automatically calculates the sensitivity of profitability to the uncertainty of yields and prices in both tabular and graphical form. The model also will calculate expected, best-case, and worst case values for crop profitability, given the uncertainty of crops and yields. The model can be used to evaluate profitability of farm operations for any scenario of yield, price, and cost.

F.2.3.3.8 Valuation of Ecological Resources and Functions (Scott et al. 1998c). Ecological resources are natural resources that provide certain necessary but overlooked system-maintenance functions within ecosystems. Environmental economics involve the search of an appropriate analysis framework to determine economic values of such resources. This paper presents a framework that estimates and compiles the components of value for a natural ecosystem. The framework begins with the ecological processes involved, which provide functions within the ecosystem and services valued by humans. The additive or competitive nature of these values is assessed, and these values are then estimated for undisturbed habitat through conventional and unconventional techniques. The framework is applied to ecological resources in a shrub-steppe dryland habitat being displaced by development in the vicinity of the Tri-Cities (Pasco-Kennewick-Richland). The paper first determines which functions and services are mutually exclusive (for example, farming vs. soil stabilization), and which are complementary or products of joint production (for example, soil stabilization and maintenance of species). Benefit transfer principles are applied with contingent valuation methodology (CVM), travel cost methodology (TCM), and hedonic damage-pricing (HDP). Finally, some upper-limit values are derived for more difficult-to-value functions through the use of "human analogs," which, it is argued, are the most appropriate method of valuation under some circumstances. The highest values of natural shrub-steppe habitat appear to be derived from soil stabilization.

F.2.3.3.9 Valuing Effects of Climate Change and Fishery Enhancement on Chinook Salmon (Anderson et al. 1993). This project represents a continuing multidisciplinary analysis of species preservation in the Yakima River basin, specifically in the context of salmon restoration and global climate change. Climate change and planned habitat improvements impact the product and economic value of spring Chinook salmon in the Yakima River. A Chinook salmon's total economic value includes the summation of the existence (nonuse), commercial, recreational, and capital values. The analysis presented in the paper uses benefit-transfer techniques from a larger body of studies to estimate the four components of value for estimated changes in Chinook salmon populations resulting from regional climate warming. The tools used in this study can be applied to any biological resource over a long term.

F.2.3.4 Socio-Cultural Impacts Conceptual Models. Efforts have begun to assess the social, cultural, and quality of life impacts associated with the Hanford Site. CRCIA Part II specified such analyses as representing the breadth of risks and impacts to be available in the future for decision-makers.

Cultural resource assessments are included in the EISs conducted under NEPA. Cultural resources are defined as any district, site, building, structure, or object considered to be important to a culture, subculture, or community for scientific, traditional, religious, or other reasons. EISs describe the affected environment that is associated with the federal agency actions being evaluated, the environmental consequences associated with implementing the actions, any mitigation measures, and the cumulative impacts. Impacts on cultural resources may include damage or destruction of archaeological and historic sites and artifacts, as well as disruption of religious and traditional uses of the Hanford Site by American Indians. The most recent EISs for the Hanford Site include the TWRS EIS and the HRA EIS.

Methodologies are available for assessing social, cultural, and quality of life impacts. The EPA has prepared *A Guidebook to Comparing Risks and Setting Environmental Priorities* (EPA 1993). In addition, some methodologies have recently been developed for this region that are included in this conceptual model (Harris and Harper 1998; Harper and Harris 1999). A few examples exist where such impact analyses have been applied to the Hanford Site.

F.3 RISK AND IMPACTS CONCEPTUAL MODEL PROPOSAL FOR SAC (REV. 0)

The proposed risk and impacts conceptual model includes the elements required to assess the cumulative effects of Hanford Site contaminants on the ecology, human health, economic and cultural uses of Columbia River and its environs. The approach for defining the larger set of potential impacts for the assessment and obtaining feedback from stakeholders, regulatory agencies and tribes is based on the use of dependency webs as described in Harris and Harper (1998).

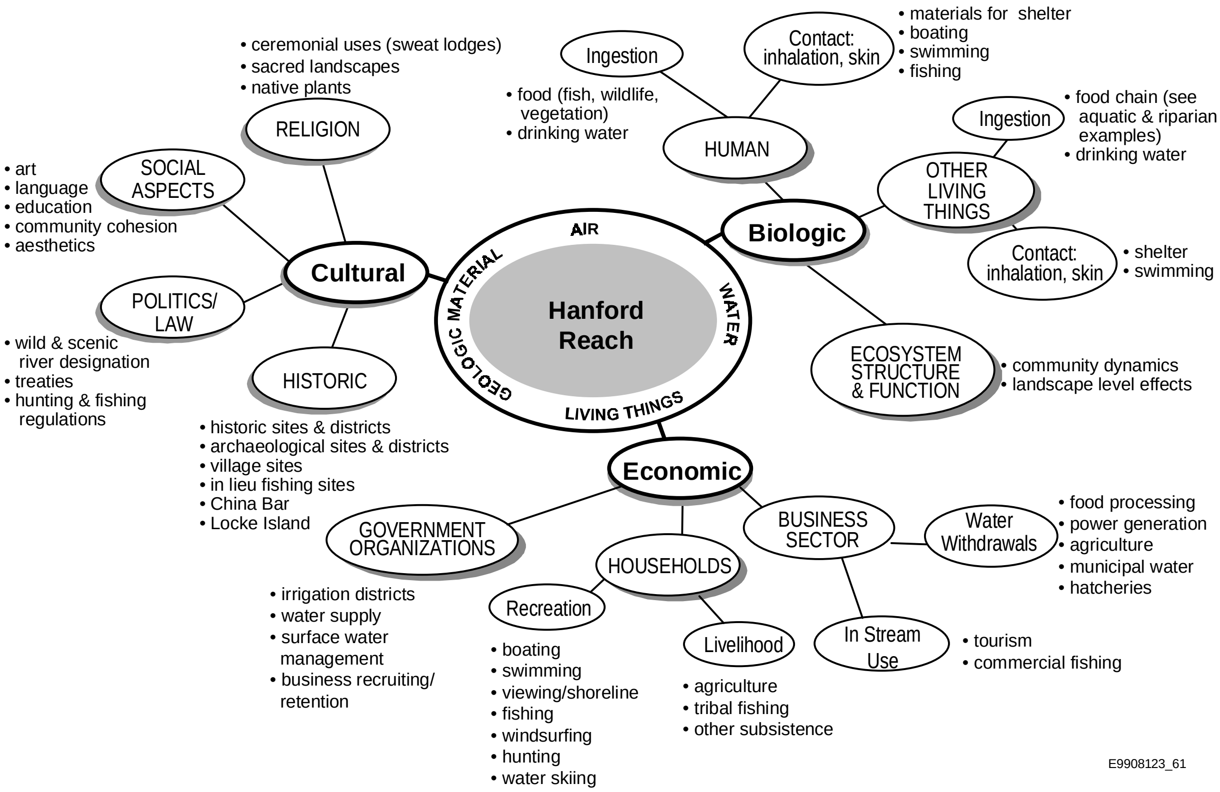
Dependency webs are relational descriptions or influence diagrams composed of the resources (air, water, geologic material, and living things) potentially affected by Hanford contamination and their *uses, functions, goods,* and *services* at selected locations where contamination and impacts are likely to occur. The dependency web developed for the Hanford Reach illustrates the concept (Figure F-2). *Uses* are things people or animals do at the location that are dependent on natural resource quality, such as recreation or public water intake or seasonal nesting grounds for birds. *Functions* are dynamic roles that elements of the local area play within the area or within a larger ecosystem. Examples are nutrient production needed by local fauna and migratory birds. *Goods* are tangible items of value to plants, animals, or people, such as food and medicine obtained from the location. *Services* are processes or end products of importance to people, such as soil stabilization provided by intact groundcover, which in turn reduces dust.

The webs are intended to describe what is potentially "at risk" along the contaminant migration path, and what is at stake if those locations become contaminated. The webs will include conventional human and ecological food chains, as well as other human and environmental functions and services co-located with the affected site or resource. Some of those uses, goods, or services could provide a pathway to human exposure, while others lead to ecological effects, adverse cultural impacts, and so on. These elements are then organized into a web of relationships. The initial general set of webs does not reflect the connections, but instead tends to identify what is potentially at risk.

These webs were initially constructed by thinking of what's important and valued at a location, then getting other peoples ideas of what's important. They were developed by asking questions about an area and using information from published documents (e.g., CRCIA, Hanford Reach Environmental Impact Statement [EIS], Eastside EIS, Hanford Remedial Action EIS, Dredged Materials Supplemental EIS). Some of the questions are:

- What is valuable about the Reach as a whole?
- What resources are within the Reach?

Figure F-2. Hanford Reach Dependency Web.



- How many ways is each resource important?
- What are the links between resources?
- How do we select metrics and ways to measure impacts?

In the summer of 1999, the GW/VZ Project engaged the public in identifying resources and uses important to them at four locations along the Columbia River from the Hanford Site along the Hanford Reach to the Lower Columbia and Coastal Areas. The webs helped define the uses of the resources in these broad areas that could be potentially affected by contamination, the biologic resources potentially at risk, and likely human exposures.

The study area for SAC (Rev. 0) is focused on the water resources of the Hanford Site and the Columbia River from Priest Rapids Dame (including the Hanford Reach) to McNary Dam (Figure F-3). Figure F-4 shows the dependency web for the McNary pool, which is slightly different from the one for the Hanford Reach.

Ecological, human health, economic and socio-cultural risks and impacts will be assessed in the Columbia River, along the river shoreline, and through the use of groundwater on the Hanford Site. The following sections provide more detail of the conceptual models for the risk assessments and impact predictions over this study area.

Figure F-3. Study Area for the Risk and Impacts Conceptual Model.

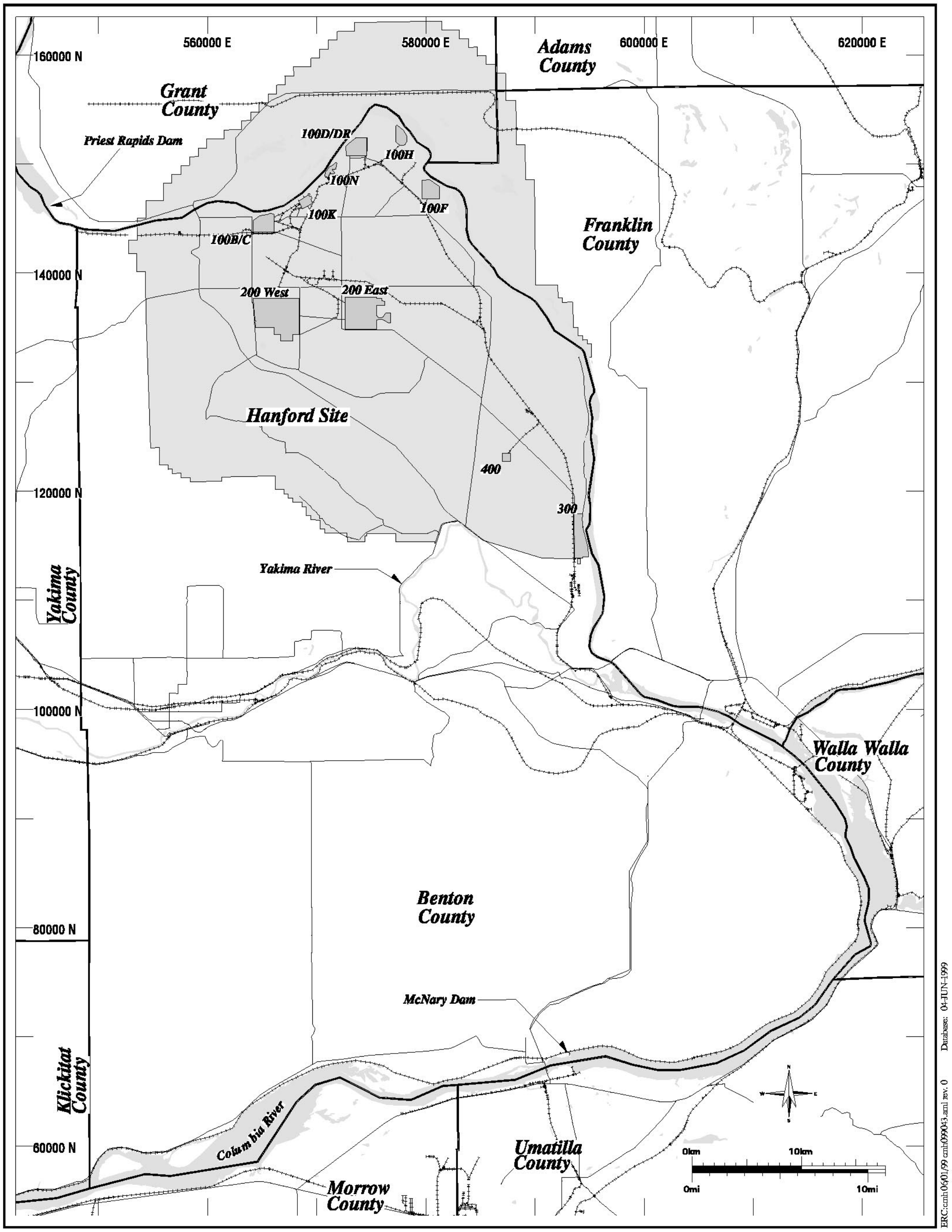
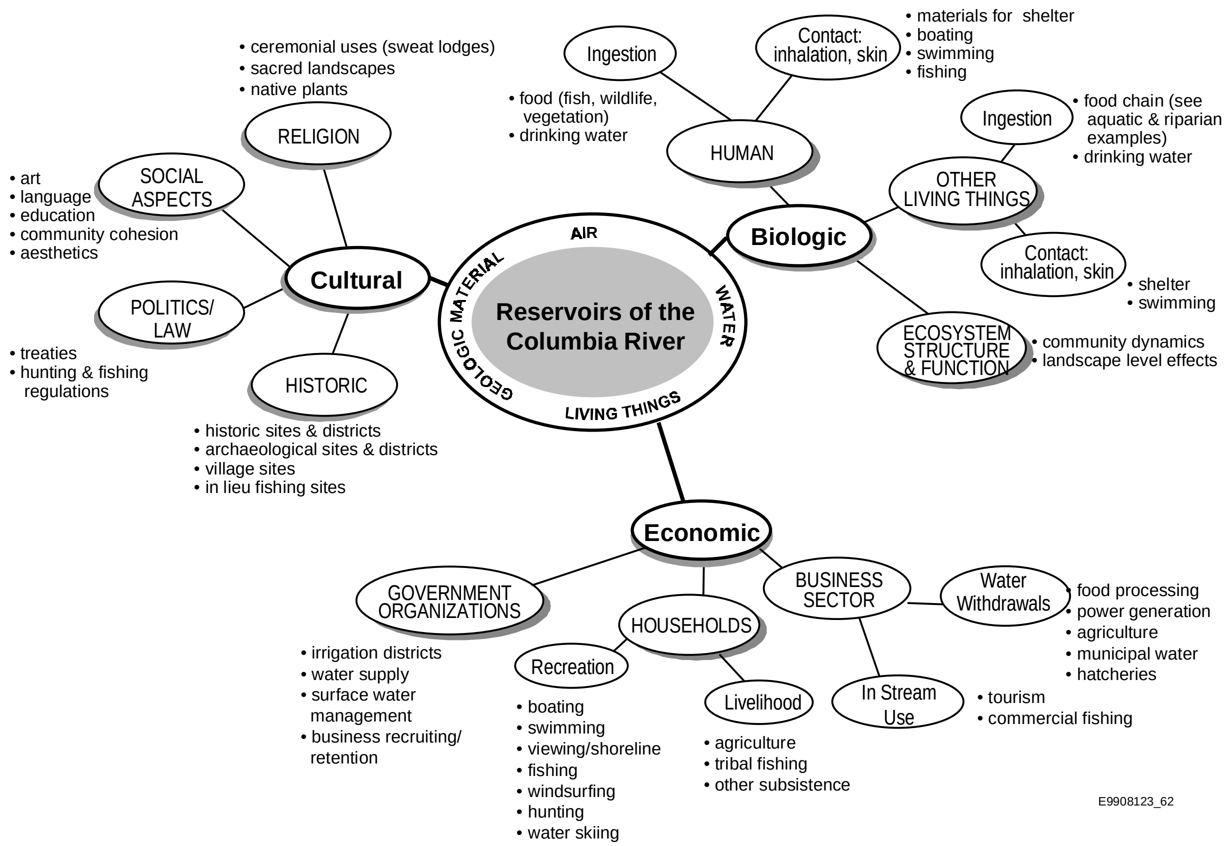


Figure F-4. Dependency Web for the McNary Pool.



F.3.1 Ecological Risk Conceptual Model

The ecological risk assessment for the SAC is to determine potential risk in the environment from COPC that remain after the closure of the Hanford Site. Thus, the ecological conceptual model focuses on exposure of biota to COPC and the resultant toxicological impacts (Figure F-1). The contaminants of concern are primarily those that originated during nuclear weapons production, although contaminants from other operations have not been excluded.

Ecological risk includes an exposure component and consequently, it relies on knowing the spatial domain of a set of COPC. The COPC locations in the environment are largely defined by what is transported through the groundwater and into the Columbia River. Therefore, the ecological risk conceptual model relies on other SAC technical elements for information. The conceptual models for the Groundwater and River technical elements of SAC, which address the transport of COPC, are used in assessing ecological risk. The transport models are expected to produce estimated concentrations of COPC in the various media associated with the SAC (Rev. 0) study area.

Given a COPC concentration at some location in the environment, the ecological risk assessment will estimate the probability of an adverse effects and determine potential risk. Risk is the joint probability of (1) exposure at or above a given level and (2) a toxicological response at that level.

F.3.1.1 Ecological Risk Conceptual Model Proposal for SAC (Rev. 0). The conceptual model for the ecological risk assessment of SAC (Rev. 0) is composed of two parts. The first part deals with exposure to COPC, the second with translating exposure into effect (Figure F-5). Exposure is further separated into aquatic (river) and terrestrial (riparian) exposure pathways (Figure F-6).

Figure F-5. Ecological Conceptual Model for SAC (Rev.0).

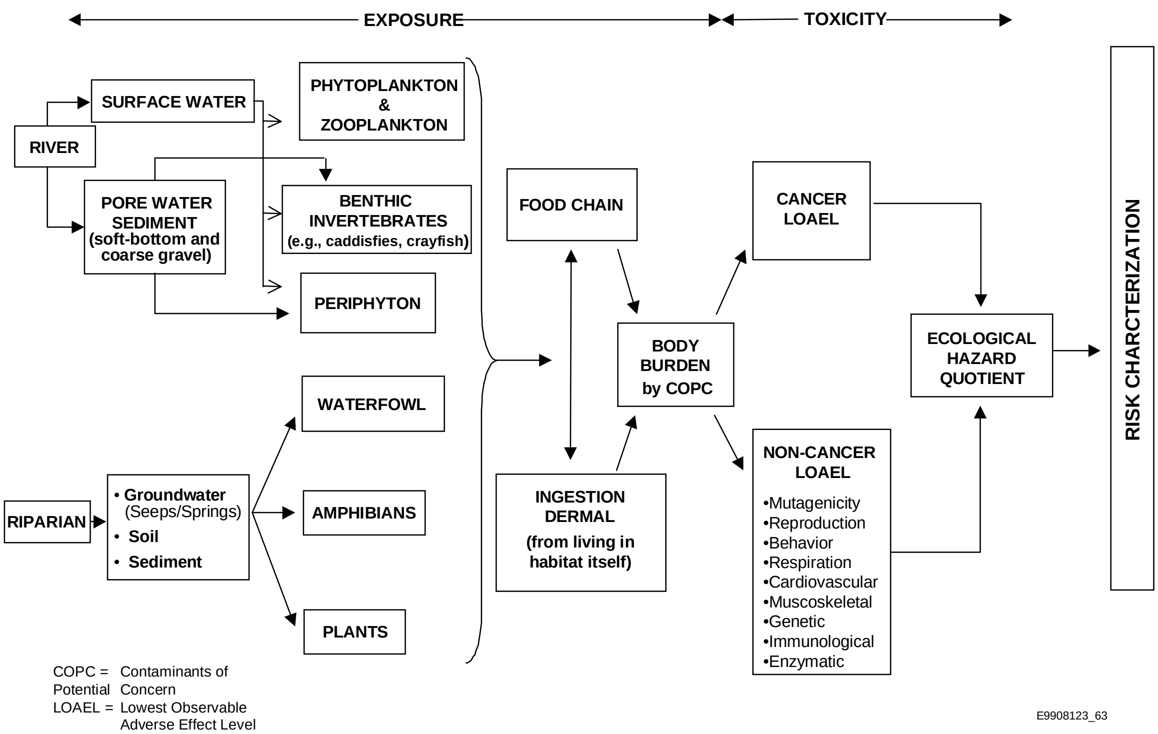
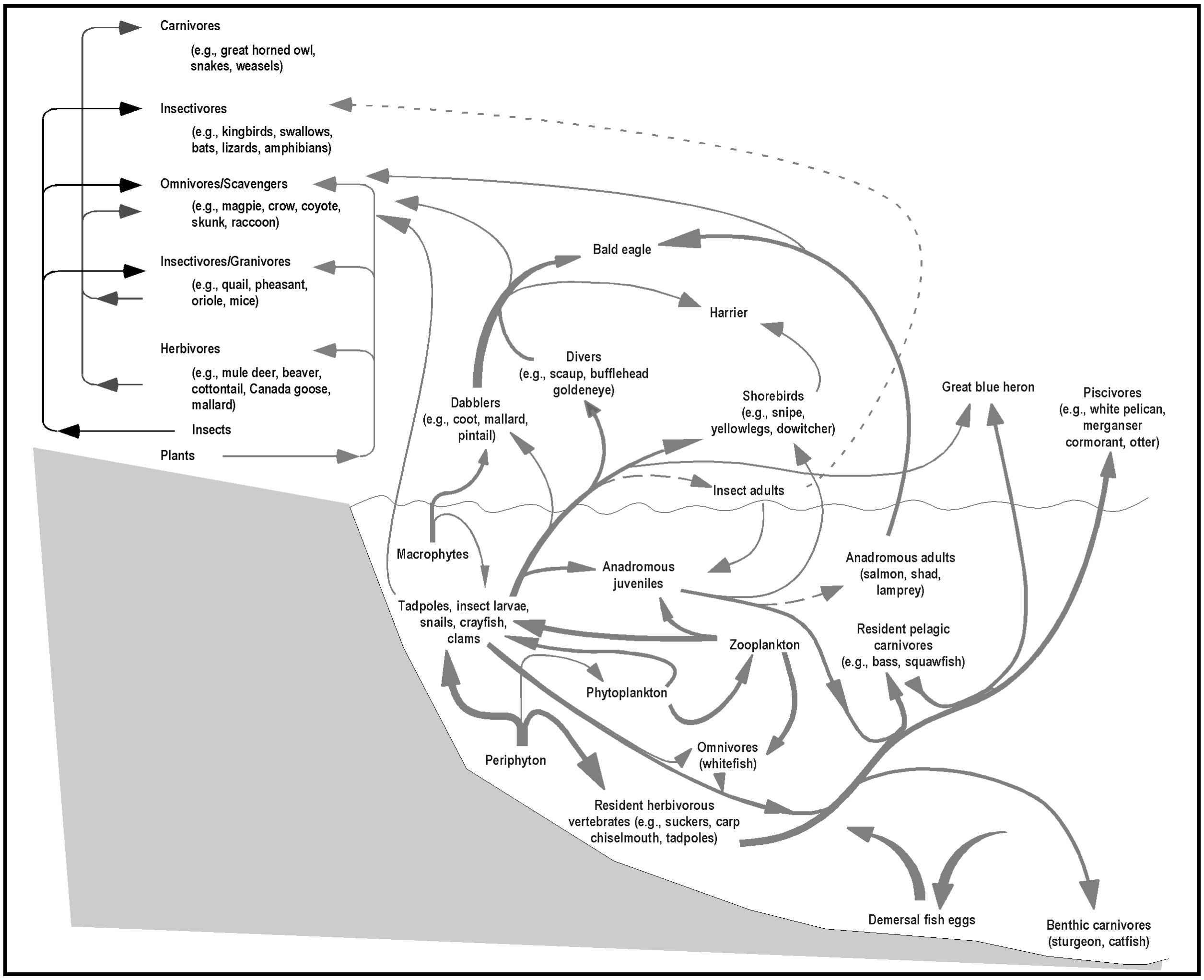


Figure F-6. Conceptual Model of Food Chain Exposures for Riparian and Aquatic Species.

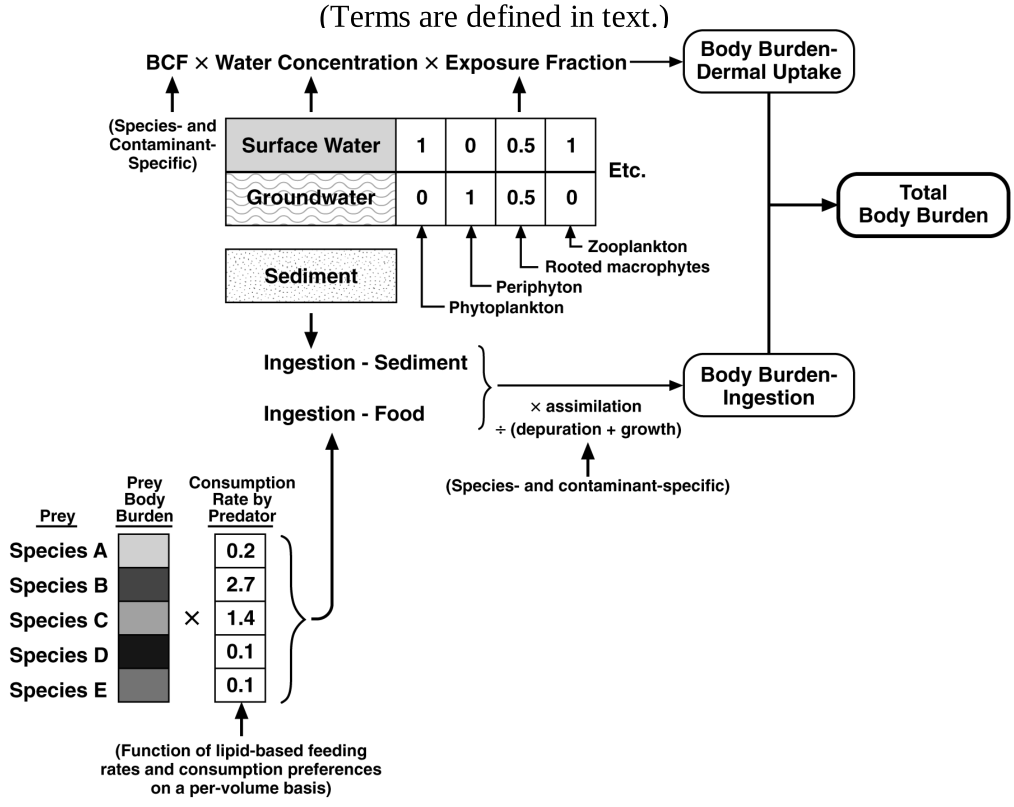


F.3.1.1.1 Exposure – Aquatic Systems. The conceptual model for SAC (Rev. 0) of the ecological risk assessment follows the model put forth in the CRCIA Part 1 (DOE 1998a). It is based on the following logic. Plants (macrophytes, periphyton, and phytoplankton) absorb COPC that are in surface water. Macrophytes, which have roots, are also exposed to contaminants from sediment and pore water. Aquatic animals (that is, animals that obtain oxygen from water) may be exposed to environmental contaminants by ingestion of contaminated food in their diet and/or exposure to COPC in their habitat. Habitat exposures can be generated through dermal absorption or respiration of COPC in surface water, sediment, or pore water. These exposure pathways are highly dependent on the life style of the species and life stage under analysis. Table F-3 summarizes the river exposure pathways for aquatic life that are represented in Figure F-7.

Table F-3. Exposure of Aquatic Life to Contaminants of Potential Concern

MEDIA				ROUTE	RECEPTOR
Surface water	Sediment	Pore water	Biota		
AQUATIC PLANTS					
X	X	X		Absorption	Periphyton
X				Absorption	Phytoplankton, Zooplankton
X	X	X		Absorption Root uptake of water	Macrophytes
AQUATIC ANIMALS (Species and lifestyle dependent)					
Surface water	Sediment	Pore water	Biota		
	X	X	X	Absorption Ingestion	Benthic Invertebrates
	X	X		Absorption	Fish Eggs
X	X	X	X	Absorption Respiration Ingestion	Developing Fish
X	X	X	X	Absorption Respiration Ingestion	Mature Fish

Figure F-7. Conceptual Model of Exposure for Aquatic Species.
(Terms are defined in text.)



The concentration of COPC in the tissues of an organism is a function of the following factors:

- The amount of contaminant present in the exposure media (water, sediment, or food)
- The rate or fraction of the contaminant crossing the organism's integument, such as gill membrane or gut membrane
- The rate of loss of the COPC via metabolic conversion or excretion (depuration)
- The rate of dilution by growth.

Figure F-7 shows how uptake of COPC in water and sediment can be combined with dietary ingestion of COPC to determine a body burden for aquatic life.

F.3.1.1.2 Exposure -- Terrestrial Systems. In Figure F-6 potential exposure pathways of riverbank ecosystems to COPC are considered by the riparian pathway. Plants may be exposed to COPC in soils/sediments or groundwater seeps via uptake through their root systems. The leaves and stems of plants can also be exposed to COPC in soils through air-transported vapor or particulate deposition arising from wind erosion or rainsplash. Similarly; waterfowl, amphibians, and other biota may be exposed to COPC by living in the riparian habitat, or through the food chain. Exposure of terrestrial, or air-respiring animals, may occur via ingestion of contaminated food or water, dermal exposure to contaminated soil or water, and/or inhalation of air-borne contaminants. Table F-4 summarizes the riparian exposure pathways represented in Figure F-6 for terrestrial life.

Table F-4. Exposure of Terrestrial Life to Contaminants of Potential Concern.

MEDIA				ROUTE	RECEPTOR
Ground water	Sediment /Soils	Airborne Particulate or Vapor	Biota		
PLANTS					
X	X	X		Root uptake of water Absorption Respiration	Vascular Plants
ANIMALS (Species and lifestyle dependent)					
Surface water	Sediment /Soils	Airborne Particulate or Vapor	Biota		
X	X	X	X	Absorption Ingestion Respiration	Animals

The concentration of COPC within the tissues of terrestrial organisms is a function of exposure rates, environmental concentrations, absorption rates, depuration rates, and growth rates similar to aquatic species noted above. One factor controlling the exposure rate is the fraction of time individuals are exposed to a medium, such as air or food, containing COPC. Because animals are mobile at one or more periods of their lives, they could experience concentrations ranging from zero to the maximum concentration entering the river environment in the groundwater. In the conceptual model, this is addressed by two parameters: area-use fraction and seasonal-use fraction. Area-use fraction is the proportion of time an organism is exposed to an area with a given COPC concentration while in the SAC (Rev. 0) study area (Hanford Reach to McNary Dam). The seasonal use fraction is the proportion of an individual's life that is spent within the SAC (Rev. 0) study area.

As shown in the figures above, once COPC enter the biological environment, they may be transported through the food chain. Figure F-5 is the conceptual model for food chain exposures in the riparian and aquatic ecosystems of the study area. For example, COPC in groundwater may enter plants and accumulate in edible tissues. Herbivores consume this plant material, along with any COPC deposited on the plant surface as particulate matter. They may also ingest soil directly, and may consume river water that may also contain COPC. The tissues of herbivores will then reflect their accumulated exposure to COPC. Omnivores and carnivores will thus consume prey that has integrated the various COPC they have encountered through their lifetime.

F.3.1.1.3 Effects. Exposure to COPC results in one of three consequences, depending on the exposure level and regime:

- No effect
- An adaptive response
- An adverse effect.

No effects result when exposure levels are below the threshold of significant physiological response. At higher exposure levels, some COPC may induce an adaptive response in the exposed organism. Adaptive responses include behavioral changes (e.g., avoiding some threshold of COPCs), biochemical/physiological changes (e.g., induction of enzymatic pathways to detoxify COPC or repair DNA), or structural changes (e.g., proliferation of metal exchange sites on gills). Adverse effects arise when the exposure exceeds the organism's capacity to deal adaptively with the chemical or radionuclide.

Radiological effects are a function of the energy deposited in the receiving biological tissues and the relative biological effectiveness of the radiation (NRC 1990). The conceptual model for radiation exposure will therefore combine radiation doses on the basis of relative biological effectiveness.

Chemical effects arise from specific actions on the structural, genetic, and enzymatic components in the exposed organism. COPC have various effects, which include narcosis (being rendered immobile) (for example, trichloroethylene), neural toxicity (for example, mercury), and enzymatic disruption (for example, copper). In combination, COPC effects may be independent, additive, synergistic, or suppressive. The conceptual model accounts for multiple COPC by grouping those with similar modes of action and treating them as additive unless research data are available that suggest otherwise. Effects on individuals can produce effects on populations and their attributes if the effect is severe enough and includes a sufficient fraction of the population. Higher-order effects include such responses as decreased population sizes, decreased population growth rates, increased rates of tumors, or evolutionary (genetic) changes. The key consideration here is that higher order effects do not appear without effects occurring at the individual level of organization.

Toxic effects of COPC on certain populations can impact other, less-exposed ecosystem components. Such effects can arise when the organisms experiencing toxic effects are: 1) key prey for other organisms; 2) predators that limit the local abundance of prey; 3) involved in nutrient cycling; or 4) primary components of the nonfood habitat of other species. These indirect effects are included within the SAC (Rev. 0) conceptual model.

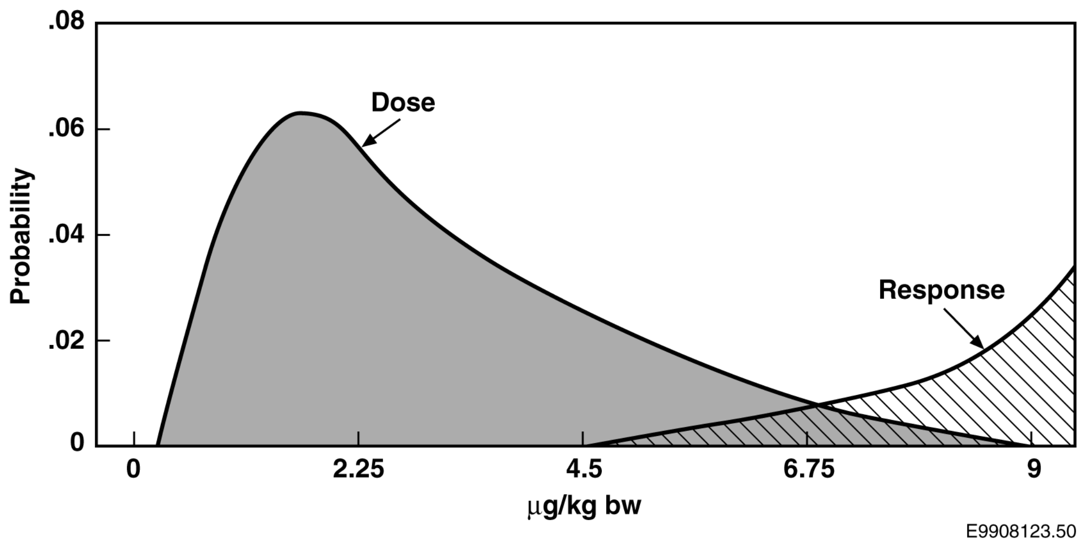
The focus of SAC (Rev. 0) is to develop a capability to estimate future effects on resources from the composite Hanford inventory of COPC. The SAC will support DOE decisions regarding cleanup actions; thus, the primary focus of the ecological risk assessment must be on defining COPC levels that are below those that can cause adverse effects on individuals of protected species and populations of other species. Consequently, the SAC (Rev. 0) conceptual model focuses on determining the probability of adverse effects at the individual level organization, as this is protective of populations.

The primary ecological values identified in SAC (Rev. 0) study set involve the long-term survival and health of the populations of species being considered. Because the SAC is concerned with assessing whether any toxic effects would result from exposure to SAC (Rev. 0) COPCs, the toxic responses to be evaluated must reflect the lowest level of toxic effect. The toxicity response selected for SAC (Rev. 0) conceptual model is the lowest observed adverse effect level (LOAEL), with “level” expressed as either a concentration or a dose. A LOAEL is the lowest chemical concentration or dose that causes an adverse effect that is statistically significantly different from the controls (EPA 1992). Because most organisms within the Hanford Reach would be exposed over a long term, the toxicological benchmarks that will be used must reflect chronic exposures (that is, the exposure duration extends for at least 10% of the expected lifetime of the individuals) (Suter 1993).

The conceptual model compares chemical and radiological toxicity responses with estimated exposures for each of the SAC (Rev. 0) species. The conceptual model dealing with effects will compare the estimated distribution of exposure for each SAC (Rev. 0) species at each exposure site to the toxicity-response distribution for that species and COPC (see Section F.8 for additional discussion). This approach, which is a variation on the quotient method (EPA 1996), will provide an estimate of the risk of exceeding a toxicological threshold. An example is shown in Figure F-8.

Risk includes the probability for exposure to a COPC. In Figure F-8, the hypothetical probability distribution of exposures of individuals to a given COPC is shown as a shaded; the probability of a toxic response is shown as hatched. The risk of exceeding a LOAEL for the hypothetical exposure scenario is the fraction of the exposure distribution that overlaps that of the response.

Figure F-8. Risk Probability for Exposure to a COPC.



F.3.1.1.4 Ecological Impacts and Metrics for SAC (Rev. 0). Ecological risk metrics are measures which can demonstrate an adverse impact from a COPC to a receptor. Table F-5 summarizes the ecological impacts and metrics for SAC (Rev. 0).

Table F-5. Ecological Impacts and Metrics for SAC (Rev. 0).

Impact	Metric
Key Individual Species	Lowest Observed Adverse Effect Level (LOAEL) for toxicity of individual COPC (chemicals/radionuclides) to an individual receptor .
Ecosystem	Food web for aquatic and riparian ecosystem. Ecosystem structure and function.

F.3.1.2 Dealing with Uncertainty in the Ecological Risk Conceptual Model. The proposed SAC (Rev. 0) uncertainty approach is a Monte Carlo technique that has the following major attributes:

- Specialized sampling techniques would be employed to reduce computation time.
- Complex or moderately complex models would be linked together into a system model.
- Release and transport calculations would be conducted and the results stored for later use by risk and impact models.

More discussion on this overall approach is provided in Appendix G.

Implementation of this Monte Carlo approach would require running multiple simulations with the ecological risk model. The ecological risk model would use contaminant concentrations from other component models, thereby incorporating the uncertainty induced by the other modeling components. In SAC (Rev. 0), a subset of the ecological model parameters would be described using statistical distributions. Examples of the parameters that could be varied in a statistical fashion are bioconcentration factors, the fraction of the contaminant crossing the organism's integument (such as gill membrane or gut membrane), or the rate of dilution due to organism growth.

The Monte Carlo approach yields a suite of ecological risk results that incorporate the uncertainties in the entire fate and transport modeling sequence. These results address parametric uncertainty in the models. If one or more alternate conceptual models are incorporated in the modeling steps, the results can be used as a partial indicator of conceptual model uncertainty. Integration of the risk elements will incorporate uncertainty in the information passed between elements.

Uncertainty in the ecological risk can also be described in qualitative terms. The following are some pros and cons of the choices made for the ecological conceptual model. Each selection bears uncertainty that will be an inherent part of the assessment.

F.3.1.2.1 Transient vs. Equilibrium Exposure Modeling. Transient modeling accounts for the temporal nature of exposure and the temporal variability in the factors influencing exposure and transport, such as water temperature. Equilibrium models are computationally simpler and assume conditions have reached a steady state. In some cases, transient exposures and resulting tissue concentrations may exceed those found in steady state or equilibrium models (for example, Newman 1995). However, an equilibrium model will perform adequately for the conditions to be evaluated under SAC (Rev. 0).

F.3.1.2.2 Bioavailable vs. Nonbioavailable Dynamics. The conversion of chemicals (primarily heavy metals) from bioavailable to nonbioavailable states is an important issue for the model; however, data are limited that will allow predictive and mechanistic estimations of mass within these two states. The model will be calibrated using regional data sets on water, sediment, and organismal concentrations of heavy metals to address this issue.

F.3.1.2.3 Uptake/Depuration, Behavior of Nutrients, Micronutrients, and Analogue COPC
Elemental COPC in SAC (Rev. 0) may be classified into those that are essential to biological systems, those that are chemical analogues of essential elements, or those that have no biological function (Table F-6). In addition, sulfates, nitrates, and ammonia (as ammonium cation) are plant nutrients. Most organisms are able to regulate uptake, metabolism, and depuration of nutrient elements (Chapman et al. 1996, Phillips and Rainbow 1989). Thus, the concentration of nutrients (i.e., calcium or iron) in the various environmental media to which an organism is exposed can greatly affect the uptake and retention of those elements and their analogues (Chapman et al. 1996). For example, studies of water-to-organism transfer factors for strontium-90 on the Hanford Site have found differences of 6 to 7 orders of magnitude, which is probably due to differences in calcium in the water sources.

Table F-6. A Classification of Elements According to Essentiality for Life (after Beeby 1991) Using the Periodic Table of the Elements.

Period	Macronutrient		Micronutrient					Nonessential	
3	Na	Mg							
4	K	Ca	Cr	Mn	Fe, Co, Ni	Cu	Zn		
5		Sr					Cd		
6	Cs							Hg	Pb

F.3.1.2.4 Dose Conversions. Extrapolating toxicological benchmarks from species for which data are available to a species of concern will require use of a common dose metric. For terrestrial species, this is usually expressed as the dose rate, which is in units of rad/day for radionuclides and mass of chemical per unit body weight mass/day for chemicals.

F.3.1.2.5 Combining exposures across pathways. COPC may produce adverse effects at the site of exposure (e.g., dermal lesions arising from dermal exposures to contaminated soils), the site or organ of accumulation, or in the metabolically active tissues in general. Where toxicity data are available for separate exposure pathways, dose-response probabilities will be assumed to be additive across pathways. Otherwise, adverse effects will be assumed to arise when whole-body concentrations reach a critical threshold.

F.3.1.3 Assumptions/Technical Rationale for the Ecological Risk Conceptual Model. Exposures of individuals or groups to COPC must be estimated for each species in the SAC (Rev. 0) study set. This includes estimating concentrations of COPC in their prey within the study area. To accomplish this, the amount of each contaminant an individual might encounter via all exposure pathways must be quantitatively estimated.

The COPC to be addressed in SAC (Rev. 0) include organic compounds, metals (radioactive and nonradioactive), tritiated water, and nonmetallic ions. The diverse chemical and physical properties will produce diverse exposure and toxicity. The COPC also include a number of chemicals that are nutrients for plants (for example, sulfate) and/or animals (for example, copper). In addition, several of the COPC are chemical analogues for nutrients (for example, strontium). These facts may greatly affect biological exposure and toxicological effects.

Exposure estimation must address uptake from all sources, such as respiratory, dermal, and ingested. Direct consequences of exposure include toxicity and increase in body burden in the exposed individuals. Changes in the amount of COPC within the exposed organism are a consequence of the concentrations the individual experiences in the various environmental media, its encounter rate (for example, respiration volumes) with the media, the amount absorbed, the loss rate arising from metabolism or excretion, and growth dilution.

For aquatic species, a standard parameter used to describe the water-to-organism transport phase is the species- and chemical-specific bioconcentration factor (BCF). The BCF is calculated as the equilibrium body burden of a chemical in an individual divided by the water concentration when uptake is limited to the water phase only (that is, no contaminated food is eaten by the species in question). Use of this parameter will be limited to those cases where reported concentrations reflect water-only exposures of short duration such that growth dilution effects are minimal.

The equilibrium body burden can be affected by growth dilution. As an organism adds mass to its body, any COPC within the body are effectively diluted. Thus, growth will act to decrease tissue concentrations of COPCs.

For SAC (Rev. 0), most animals will be treated as being composed of a single compartment. In other words, the conceptual model will not account for tissue-specific differences in COPC concentrations, although these differences do exist. The justification for this simplification is that most organisms are consumed whole (a primary exception being large bivalve molluscs) by other organisms, and thus predators experience the total amount of COPC within the organism, rather than the amount within a specific tissue. Terrestrial plants and macrophytes will not be treated in this fashion, as most animals in the region do not consume plants in their entirety, but instead focus on individual tissues such as seeds, leaves, or bark.

For SAC (Rev. 0), the body burdens of COPC within all organisms are assumed to be at equilibrium with the environment. In other words, the concentrations will result from long-term (generally, in the range of days) exposure under steady conditions within a given locality.

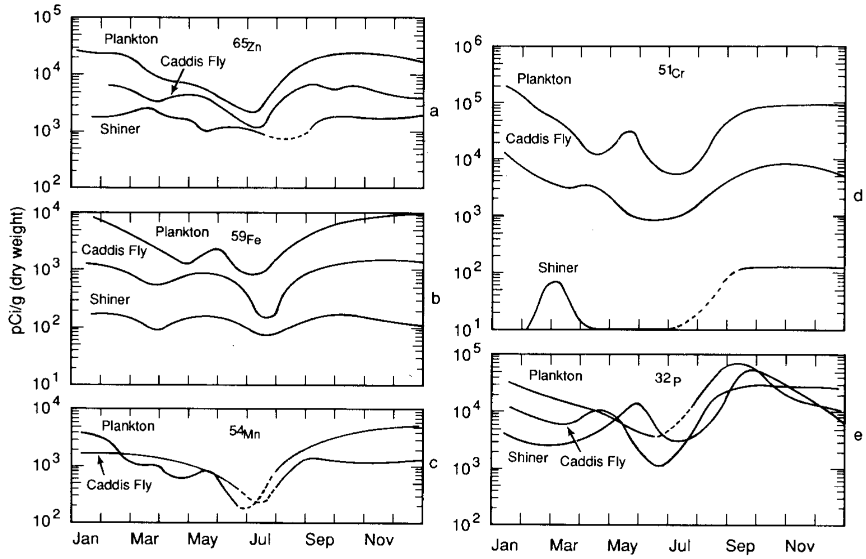
The amount of prey consumed by a predator is assumed to be a function of its field metabolic rate, the amount of energy contained in each prey type consumed, and the proportion of each prey type consumed.

A number of ecosystem properties produce variation in tissue concentrations of COPC, especially in aquatic biota. Such variations therefore affect ingestion exposures of herbivores and predators. Primary sources of variation include water temperature, ambient light level, and water clarity, all of which vary seasonally. Yearly variation in radionuclide concentrations of Columbia River biota may cover an order of magnitude (Figure F-9). To determine whether adverse effects are possible at a given COPC concentration in SAC (Rev. 0), it will not be necessary to account for this range of variability directly. Instead, the conceptual model will assess exposure and risk under conditions when concentrations in biota will be at their peak.

Ecologically meaningful effects of COPC exposure of individual organisms always result from low-level toxic effects. However, low-level effects do not always produce ecologically meaningful effects. Thus, evaluating risk on the basis of comparison to low level effects on individual organisms will be protective of the ecosystem.

For most of the COPC, toxic effects are produced by critical body burdens or whole-body doses summed across all exposure pathways. This approach will be used to combine doses across exposure pathways.

Figure F-9. Seasonal Changes in Radionuclide Concentrations in Columbia River Biota During Operation of the Once-Through-Cooling Reactors (Watson and Cushing 1969).



F.3.2 Human Health Risk Conceptual Model

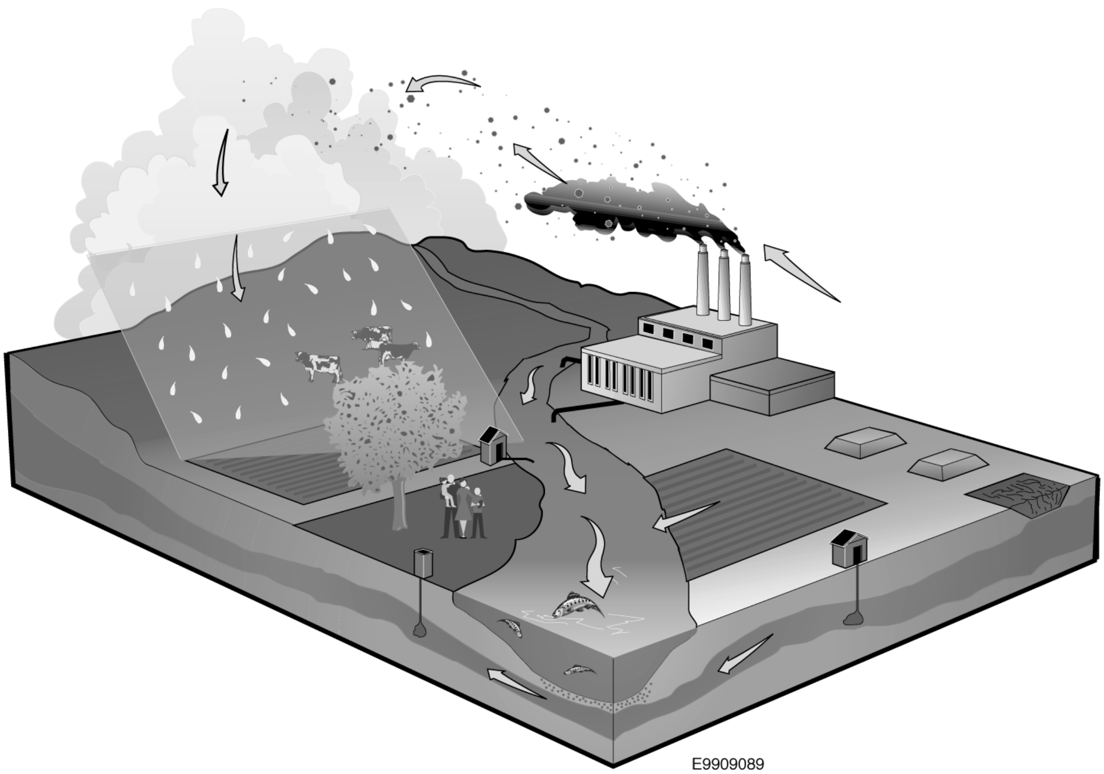
The Human health risk conceptual models are mostly regulatory driven. These models are typically prepared as part of the risk assessment process for determining cleanup criteria for contaminated sites, using guidelines developed for EPA's Superfund program. In addition, the conceptual models are applied to hazard waste management.

The human health conceptual model for SAC (Rev. 0) is linked to the Vadose Zone, Groundwater, and River conceptual models that provide information regarding the concentration of contaminants and their location. From this information, the potential receptors and routes of exposure will be addressed. In this report, the receptor and route of exposure are referred to collectively as the human health conceptual model. The conceptual model for human health risk consists of two steps: 1) identify possible scenarios of human activities and associated exposure parameters used as the basis for estimating the range of human exposures; and 2) quantify the potential risk to individuals based on the selected scenario.

F.3.2.1 Human Health Risk Conceptual Model Proposal for SAC (Rev. 0). The objective of the human health risk assessment for SAC (Rev. 0) is to determine whether Hanford-derived contaminants from the Columbia River pose a threat to humans in the study area from Priest Rapids Dam to McNary Dam. The proposed conceptual model shall be comprehensive enough to evaluate a wide variety of the human-exposure scenarios identified through the use of dependency webs. The model also must be flexible enough to quickly and efficiently incorporate new scenarios requested and recommended by interested groups.

Contaminants in the Columbia River and its associated shoreline and sediment could affect people involved in a wide range of activities. These activities are captured in the scenarios that will be used in the assessment. Figure F-10 is a generalized illustration of the various pathways that bring people into contact with contaminants. For SAC (Rev. 0), only past operations at the Hanford Site will be evaluated.

Figure F-10. Generalized Illustration Contaminant Pathways and Human Activity for the Human Health Conceptual Model.

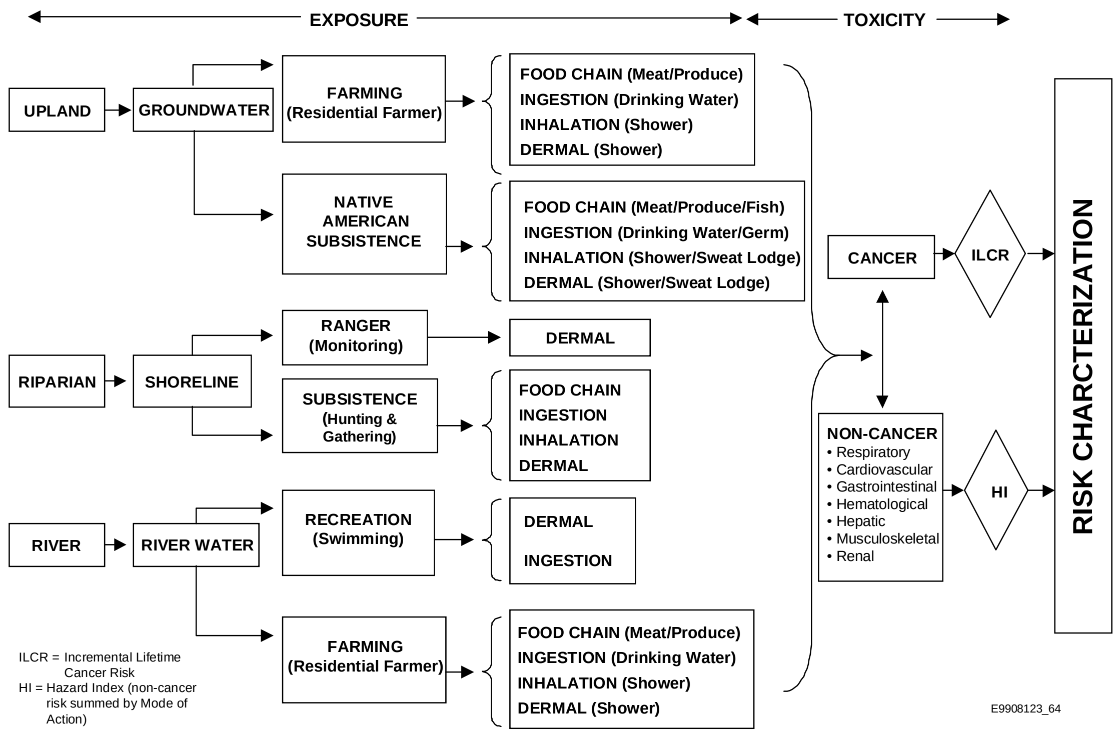


The SAC (Rev. 0) will be based on standard scenarios and exposure parameters presented in HSRAM, and additional scenarios and exposure pathways on the basis of stakeholder input. Receptors for locations and habitats of concern will be evaluated in the SAC (Rev. 0). Locations of concern are defined in CRCIA Part II (DOE 1998a) as those places where groundwater enters the Columbia River, holdup locations related to sediment deposition, and dissolved-phase transport. Habitats of concern are those places where the entry of contaminants into the food chain and other exposure pathways are likely to occur. For SAC (Rev. 0), potential human exposure for the locations and habitats of concern within of the upland areas of the Hanford site through to McNary Dam will be evaluated.

The first step in using the human health conceptual model is to identify COPCs. Modeling results and environmental characterization data identify a large number and variety of contaminants that are related to past Hanford Site process history. However, only a subset of these contaminants will migrate from the release sites and be evaluated in the human health risk assessment. (For a more complete discussion of the COPC, see Appendix A.).

Migration of the COPC to the locations of concern evaluated in SAC (Rev. 0) is being modeled by the SAC vadose zone and groundwater tasks. These modeled concentrations of COPCs both spatially and temporally will be used to estimate the risk to human receptors through applicable pathways. The general conceptual model for human health risk assessment, presented in Figure F-11, summarizes the exposure pathways for COPC to reach potential receptors.

Figure F-11. Human Health Conceptual Model for SAC (Rev. 0).



It is important to note that, although many pathways are possible, the conceptual model focuses on those pathways that are likely to contribute significantly to overall risks. The following elements represented in the conceptual model are necessary for a completed exposure pathway:

- A source and mechanism for hazardous-substance release
- Transport mechanism/media
- Exposure media or point
- Exposure routes
- Receptors.

All elements must be present for an exposure pathway to be completed. However, the importance of individual pathways to the overall exposure assessment may vary because of the physical characteristics of a site, the physical, chemical, and toxicological characteristics of the hazardous substances present, the probability that a pathway will be completed, and receptor characteristics (DOE 1995a).

The soil has received hazardous waste at the Hanford Site through direct disposal of liquid to soils in cribs, trenches, retention basins, burial of waste in landfills or burial grounds, and spills and leaks from storage tanks (Jaquish and Mitchell 1988). As indicated in the conceptual model, potential exposure to hazardous substances in soil can occur through several exposure routes, such as inhalation and ingestion, and through several transport mechanisms. Direct receptor contact with the soil can result in incidental ingestion, dermal exposure, and external radionuclide exposures.

Hazardous substances in soil can also be transported to groundwater. Once in the groundwater, hazard substances can be directly ingested by a receptor, or receptors may be exposed through dermal contact with the water via wells during showering, bathing, and other domestic or commercial water use. Inhalation of volatile substances in groundwater may also occur during the use of groundwater and from volatile substances diffusing through the soil to the ambient air from the groundwater. Groundwater used as an irrigation source may reintroduce hazardous substances to the soil. Hazardous substances could also be transported to livestock if groundwater is used as a water source.

Hazardous substances that have migrated to groundwater may also be transported to surface water. Groundwater flowing under the Hanford Site enters the Columbia River. The Columbia River is used as a source of water for domestic, industrial, agricultural, and recreational purposes within the study area. For example, the City of Richland uses river water to artificially recharge the unconfined aquifer. This also treats turbid Columbia River water and enhances the field capacity of the city wells. Thus, hazardous substances transported to the Columbia River could potentially be ingested, dermally absorbed during water use, and inhaled.

Hazardous substances in surface water may directly impact biota consumed by human receptors, such as bioaccumulation in fish and livestock watered with Columbia River water. These substances can also settle into sediments where contact during recreational use may occur or from which Columbia River biota can be imported. Surface water used as an irrigation source could introduce hazardous substances to the soil.

The conceptual model for human health risk consists of two steps: 1) identify possible human activities that describe the selected scenario and associated exposure parameters used as the basis for estimating the potential range of risk to human health; and 2) assess the potential risk to individuals based on the selected scenario.

Traditionally, in human health risk assessment, the potential receptors are defined and selected based on the regulatory guidelines and standards. The scenario for these defined and selected receptors can be evaluated based on exposure pathways and the receptor’s life style. In this study, the specific scenarios are not fully established, but the exposure pathways are well determined. Therefore, the first step would be to identify the range of human-exposure scenarios for evaluation. The proposed conceptual model for defining human health scenarios will be flexible enough that it would be able to incorporate any combination of the evaluated possible pathways. These pathways include resources such as groundwater, Columbia River water, sediment, and shoreline. These will be used to develop scenarios that fit the human health metrics.

The risk will be calculated using the unit risk factor (URF) concept. The URF will be evaluated based on EPA methodology. The URFs for each pathway are calculated using unit concentration within the media of interest (soil, sediment, surface water, and other resources). The URF for a selected scenario will include URFs for each carcinogenic and noncarcinogenic substance.

F.3.2.1.1 Toxicity Assessment. One component of the URF incorporates estimates of the constituent's toxicity. The toxicity-assessment portion of the human health evaluation consists of information on noncarcinogenic and carcinogenic toxicity values. Sources of general toxicity information for risk assessment are from a variety of sources, such as the Agency for Toxic Substance Disease Registry (ATSDR), toxicological profiles, the basic science of poison (Amdur et at. 1991), chemical hazards in the workplace (Proctor et al. 1988), and many others.
A complete list is presented in DOE (1995a).

The hierarchy of sources for numerical toxicity values are from the Integrated Risk Information System (IRIS), the EPA's online database, and Health Effects Assessment Summary Tables (HEAST) (EPA 1994). The IRIS and HEAST databases provide chemical-specific slope factors, weight of evidence classifications for carcinogens, reference doses for noncarcinogens, and supporting discussion and references. If toxicity information for a chemical or radionuclide is not currently available from IRIS or HEAST, then toxicity factors developed by the Environmental Criteria and Assessment Office (ECAO) for the office of Emergency and Remedial Response (those of which are not yet available in IRIS) may be used. Some states, like California, and regions, e.g., EPA Regions III and IX, have also developed toxicity values that may be reviewed for use if chemical-specific data are not available from these other sources.

Systemic toxic effects can be associated with exposure to both chemicals and radionuclides. The Reference Dose (RfD) is the toxicity value used to evaluate noncarcinogenic effects resulting from exposures to chemicals. The RfD has been developed based on the concept that protective mechanisms exist that must be overcome before an adverse effect is manifested (that is, an exposure threshold exists below which no adverse effect occurs). The RfD is developed to reflect the duration of exposure for subchronic exposure (2 weeks to 7 years) and chronic exposure (7 years to a lifetime) and the route of exposure (for example, inhalation, oral). In addition, RfD are currently being developed, as appropriate, to evaluate specific critical effects such as developmental effects that may occur because of exposure to certain chemicals.

The subchronic RfD is utilized to evaluate potential noncarcinogenic effects from exposures that occur because activities are performed for a limited amount of time (e.g., during remediation activities) or when a substance with a short half-life degrades to negligible concentration within several months. For longer exposures, the chronic RfD is utilized to evaluate potential noncarcinogenic effects. The chronic RfD is a daily exposure level that is likely to be without an appreciable risk of deleterious effects to the general public, including sensitive subpopulationns, during a lifetime.

Noncarcinogenic radiation-induced health effect can be classified as stochastic or nonstochastic (i.e., acute toxicity). Stochastic effects are those for which induction is probabilistic, and that probability is a function of the absorbed dose. In addition, there is generally believed to be no threshold dose below which a stochastic health effect cannot be induced, nor is there a dose above which such an effect is guaranteed, Example of stochastic health effects include carcinogenesis, mutagenesis, teratogenesis, and life shortening.

Acute toxicity effects are those that have a threshold dose and will occur if that threshold is exceeded. The term acute is not exclusive to exposure duration but may also be used to characterize a short, or sudden, event and is used to refer to effects that manifest over a short time period. Examples include hematological changes, cataracts of the lens of the eye, erythema, and acute radiation syndromes.

HSRAM recommended that only carcinogenic effects be routinely evaluated for radionuclides, as carcinogenesis is the predominant adverse human health effect. The EPA states that risk of cancer appears to be limiting, and may be used as the sole basis for assessing the radiation related human health risk of a site contaminated with radionuclides. It is important to distinguish the carcinogenic potential of radiation from the chemical toxicity of these elements and their compounds. The internally committed quantities that pose a significant radiation-induced cancer risk generally have an insignificant chemical toxicity. Some exceptions may occur (e.g., the nephrotoxic effects of uranium) and will be evaluated on case-by-case basis.

The carcinogenic effects are evaluated using the chemical-specific slope factor and accompanying EPA weight-of evidence determination. The toxicity values (i.e., slope factors) for carcinogens have been derived based on the concept that, for any exposure to a carcinogenic chemical, there is always a carcinogenic response (no threshold). The slope factor is used in risk assessment to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. In addition to slope factor, the likelihood that a substance is a human carcinogen is also considered. A weight-of-evidence classification is assigned to each substance, based on the strength of human and animal evidence of carcinogenicity. The EPA (1989b) weight-of-evidence classification is the following:

- Group A – Human Carcinogen
- Group B – Probable Human Carcinogen
- Group C – Possible Human Carcinogen
- Group D – Not Classifiable as to Human Carcinogenicity
- Group E – Evidence of Noncarcinogenicity in Human.

All radionuclides are classified as Group A- Human Carcinogen; therefore, further consideration of weight-of-evidence for radionuclides is not necessary.

F.3.2.1.2 Risk Results. The second step is to characterize the potential risk to humans based on the scenario selected. For the proposed assessment, the product of the evaluated scenario URFs and the concentration in the media of interest will result in the impact for that scenario at the location and time of the estimated concentration of the constituent of concern. The following relation expresses the human health risk calculation:

$$\mathbf{R_{klt,i} = \Sigma\, C_{klt}\ \ S_i^{\,urf}} \qquad (1)$$

Where $R_{klt,I}$ represent the risk of a COPC of (k) in a location (l) at a specific time (t) for receptor (i), C represents the concentration, and S_i^{urf} represents the scenario unit risk factor. The specific concentration of the COPCs for given time periods will be provided by the other SAC technical elements. The assessed impact to each receptor will be both the carcinogenic and noncarcinogenic effects. In addition, the affected organ for noncarcinogenic constituents will be identified and reported. The resultant risk will be presented spatially and temporarily. The spatial presentation will be contaminant driven, for locations where there is any contamination, the risk will be evaluated and presented.

F.3.2.1.3 Scenarios. Several receptors are considered for the SAC (Rev. 0). The lifestyles of the receptors are represented in scenarios are based on HSRAM and CRCIA Part I. These scenarios can be modified in the future based on input from regulators, Tribal Nations and stakeholders. The scenarios discussed for SAC (Rev. 0) are based on human activity within the study area, and address comprehensive impacts of Hanford-derived contaminants within the groundwater and surface water, and riparian zone. The selected receptors are two upland residents, including a residential farmer and a Native American subsistence and four Columbia River- and shoreline-users, including a ranger, a recreational shoreline user, a shoreline and/or river subsistence user, and a Columbia River residential farmer.

An upland residential farmer, who uses groundwater as the primary water source, will be analyzed. This scenario represents use of land for residential activities and agricultural production. The upland residential farmer includes producing and consuming animal, vegetable, and fruit products. A composite adult will be used as the receptor for some of the exposure pathways. The composite adult is evaluated using child parameters for 6 years and adult parameters for 24 years, with total exposure duration of 30 years. The risk for this receptor will be presented spatially for different time intervals.

The Native American scenario represent exposures received during a 70-year lifetime by a Native American who engages in both traditional activities (e.g., hunting, fishing, and using a sweat lodge), and contemporary lifestyle activities the same as the residential farmer (e.g., irrigated farming). The individual is assumed to spend 365 days per year on the site over a 70-year lifetime.

Four receptors are identified as Columbia River-users: a ranger, a recreational shoreline user, a shoreline and/or river subsistence user, and a Columbia River residential farmer. The ranger works out of an offsite facility and spends about 3 days peer week on the site (150 days/year). The ranger's onsite activities are associated with upland areas, river shoreline, and boating on the Columbia River. The ranger is assumed to work in the area for 30 years. The recreational shoreline user scenario represents exposure to contamination in the Columbia River and shoreline from swimming, boating, and other shoreline activities. These exposures would not be continuous, but would occur for 14 days per year for 30 years. The shoreline subsistence scenario will include the most conservative of the river-focused hunter and fisher, or gatherer of plant materials as presented in the CRCIA Part I (DOE 1998a). Shoreline Subsistence Scenario is based on the regional Native American inputs. The Columbia River residential farmer is similar to the upland residential farmer. The only difference between these two scenarios is the source of the water. The upland residential farmer uses groundwater within the Hanford Site, while the Columbia River residential farmer lives outside of the Hanford Site boundary and uses river water. The risk for these four receptors will be calculated for the points of maximum risk, and will be presented by plot of the maximum risk as function of river-mile location. The time of assessment will be determined based on the contaminants plume arrival time.

F.3.2.1.4 Human Health Impacts and Metrics for SAC (Rev. 0). Human health risk metrics are presented in Table F-7. These metrics are measures that can evaluate an adverse effect from the COPC to human health.

Table F-7. Human Health Impacts and Metrics for SAC (Rev. 0).

Human Health	
Impact	**Metric**
Incremental Lifetime Cancer Risk	Additive single pathway and multiple pathway cancer risk for all carcinogenic COPC (risks from radionuclides presented separately from those other for other carcinogenic COPC).
Noncancer, e.g., respiratory, cardiovascular, gastrointestinal, hematological, hepatic, musculoskeletal, renal, and others	COPC-specific, multiple pathway hazard indexes, segregated hazard indexes for COPC with similar mechanism/mode of action or affecting the same organ system.

F.3.2.2 Dealing with Uncertainty in the Human Health Risk Conceptual Model. The proposed SAC (Rev. 0) uncertainty approach is a Monte Carlo technique that has the following major attributes:

- Specialized sampling techniques would be employed to reduce computation time.
- Complex or moderately complex models would be linked together into a system model.
- Release and transport calculations would be conducted and the results stored for later use by risk and impact models.

More discussion on this overall approach is provided in Appendix G.

Implementation of this Monte Carlo approach would require running multiple simulations with the human risk model. The human risk model would use contaminant concentrations from other component models, thereby incorporating the uncertainty induced by the other modeling components. In SAC (Rev. 0), a subset of the human model parameters would be described using statistical distributions. Examples of the parameters that could be varied in a statistical fashion are exposure times, contaminated food intake rates, rate of irrigation for food crops, and exposure to impact conversion factors.

The Monte Carlo approach yields a suite of human risk results that incorporate the uncertainties in the entire fate and transport modeling sequence. These results address parametric uncertainty in the models. If one or more alternate conceptual models were incorporated in the modeling steps, the results can be used as a partial indicator of conceptual model uncertainty. Integration of the risk elements will include incorporate uncertainty in the information passed between elements.

The majority of the exposure parameters for human health risk are defined in the EPA publications (EPA 1989b, EPA 1985). RPE methodology for the AX tank farm (DOE 1999a) has documented an extensive set of parameter PDFs for its stochastic assessment that include exposure parameters for several pathways for the residential farmer's scenario. The CRCIA, Part I, has also documented PDFs for several exposure parameters for the scenarios that were evaluated (DOE 1998a).

The uncertainty in toxicity values and information can be related to the human health risk calculation. An understanding of the degree of uncertainty associated with toxicity values is an important part of interpreting and using those values. A high degree of uncertainty in the information used to derive a toxicity value contributes to less confidence in the assessment of risk associated with exposure to a substance.

F.3.2.3 Assumptions/Technical Rationale for the Human Health Risk Conceptual Model. The human health risk conceptual model assumes a unit risk approach for carcinogenic chemicals in assessing the human health impact. Unit risks are generated based on the scenarios of interest. The unit risk approach has been used in several major Hanford Site assessments, such as the HRA EIS, TWRS EIS, and RPE. The EPA supports use of URFs to assess risks. Toxic effects from exposure to noncarcinogenic chemicals will be evaluated in terms of the hazard quotient, which is the ratio of chemical intake to reference dose. Hazard quotients for COPC with similar mechanisms or modes of action will be summed to generate hazard indexes.

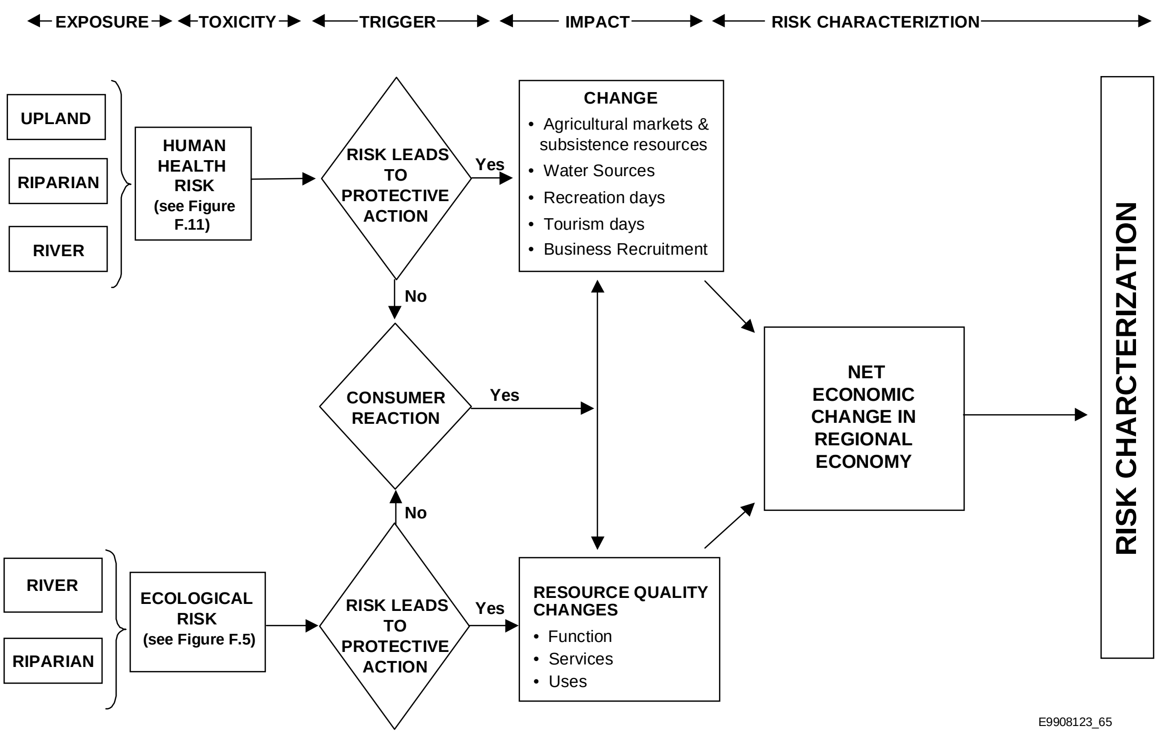
Exposure estimation will address uptake from all pathways such as ingestion, inhalation, and dermal. The exposure pathways will be evaluated for the selected scenarios and will include the following:

- Ingestion of water, soil and dust, and sediment
- Inhalation of fugitive dust and volatile from water and soil
- Dermal contact with soil, sediment, and water
- Consumption of dairy, beef, game, Columbia River fish, and homegrown produce
- External exposure from radionuclide in soil.

F.3.3 Economic Impact Conceptual Model

For economic impacts, the conceptual model has two major components, as shown in Figure F-12. The first component consists of "impact trigger mechanisms," sequences of physical and human behavior changes in response to, or resulting from, human health or ecological risks.

Figure F-12. Economic Conceptual Model for SAC (Rev. 0).



The second component reflects the processes by which particular trigger mechanisms induce impacts. This component consists of both: 1) economic market effects and changes in resource or activity values that are directly generated; and 2) indirect regional economic impacts that occur through "ripple effects" from the direct impacts. Both components are driven by information inputs from the human health and ecological risk assessments. Only the portion of the conceptual model related to human health risks is implemented in SAC (Rev. 0).

F.3.3.1.1 Impact Trigger Mechanisms. Two chains of events may lead to economic impacts, one tied to human health risks and the other to ecological risks. For SAC (Rev. 0), all of the specific impacts proposed for assessment have potential human health risks as the trigger mechanism.

As shown in Figure F-11 for human health risks, the first crucial juncture in assessing the generation of economic impacts lies in evaluating whether information as to risk levels would lead to protective actions to prevent exposure. Protective actions could involve government proscription of any use of a resource, avoidance of products or locations by the public, or both types of actions. Projecting the potential for protective action to be taken is complicated by the fact that available information may or may not accurately portray physical risks. Regardless of their relation to health risk estimates, protective actions of almost any type are likely to lead to some economic impact. The magnitude of economic impacts induced in this manner depends on the type and duration of the protective action, the geographical scope and types of resources affected, and the extent of public involvement. In the case of government proscription, compliance is rarely complete, and where avoidance is voluntary, rates of participation are likely to vary between local and nonlocal users of the avoided resource.

If protective actions have the effect of preventing health effects, then all or most health-effect impacts, including any economic ones, would be avoided. If health effects do occur, then they must be accounted for as impacts. Economic values of health care costs, lost productivity, and pain and suffering associated with health effects can be estimated; however, monetary values are not recommended for inclusion in SAC (Rev. 0) because of controversies surrounding the methodology for such an assessment. Human health risks could be specified in terms of physical risk only.

Following the conceptual model, if the human health risk were so low that no one would be likely to take protective action and no significant health effects would occur, then there would be no economic impacts through the health effects mechanism. Economic impacts would also be avoided if ecological risks were so low that no noticeable changes would be induced in ecological resources, their functions, or services.

Economic impacts derived from ecological risks are triggered when ecological resources are degraded so that their quantity or quality declines or there is a decrease in the services that they provide. Impacts may also occur if resources are perceived to be degraded so that people change their use of the resources or the value that they place on the resource use.

F.3.3.1.2 Economic Effects. Economic impacts stimulated by the trigger mechanisms may take a variety of forms, some of which involve well-defined markets for which data are available, but some of which are nonmarket in nature. Within the category of market effects, impacts may take the form of changes in either costs or revenues for economic sectors associated with the affected resource or activity. Impacts will be measured as the net change from the baseline value of activity costs and revenues for the sectors affected (as measured by income or employment, for example). Nonmarket impacts will generally be quantified through use of contingent valuation survey measures or by inference from related expenditures. An example would be the difference in the value of time and expenditures committed to windsurfing on uncontaminated water versus on contaminated water.

As a result of the role of information in the development of impacts, the severity of the health risk is only a partial indicator of the likely severity of the associated impact. Nonetheless, the impact of avoidance behaviors that are based on uncertainties or misinformation can have major economic repercussions that are likely to persist until there is a change in public perceptions of the situation.

Indirect impacts on the regional economy develop from the impacts on the economic sectors that are primarily affected. This occurs because, for example, any increases in costs of water supplies that might be borne by local residents would leave them with less disposable income for other goods and services. Decreases in revenues of local firms would similarly leave them with decreased funds available for salaries and other expenses. Both types of changes result in shrinking the regional economy, where funds recirculate among economic sectors.

The economy of the potentially impacted region has a complex structure, the features of which may have different degrees of relevance for particular analyses (for example, drinking water versus agricultural products). In some analyses, spatially defined submarkets of a single economic sector may be important while in other analyses interactions among sectors, such as the contribution of agricultural employment to household income for migrant workers, may be most salient. The distribution of net impacts among sectors will be identified and quantified, to the extent feasible, for each health category analyzed.

F.3.3.1.3 Economics Impacts and Metrics for SAC (Rev. 0). The impacts and metrics for the economic assessment are summarized in Table F-8.

Table F-8. Economic Impacts and Metrics for SAC (Rev. 0).

Impact	Metric
Proscription/Public avoidance of products	Changes in quantity sold and revenues; effects on workforce
Proscription/Public avoidance of recreational activities	Change in recreation value; effects on the workforce
Alternative water supply cost	Changes in costs (other sources)
Loss of business recruiting options	Changes in net income, employment; loss in tax base

F.3.3.2 Dealing with Uncertainties in the Economic Impact Conceptual Model. Uncertainty regarding the magnitude and duration of protective actions will be addressed by developing both "best estimates" and bounding ranges for trigger mechanism parameters.

The proposed SAC (Rev. 0) uncertainty approach is a Monte Carlo technique that has the following major attributes:

- Specialized sampling techniques would be employed to reduce computation time.
- Complex or moderately complex models would be linked together into a system model.
- Release and transport calculations would be conducted and the results stored for later use by risk and impact models.

More discussion on this overall approach is provided in Appendix G.

Implementation of this Monte Carlo approach would require running multiple simulations with the economic impact model. The economic impact model would use contaminant concentrations and other performance metrics from other component models, thereby incorporating the uncertainty induced by the other modeling components. In SAC (Rev. 0), a subset of the economic impact model parameters would be described using statistical distributions.

The Monte Carlo approach yields a suite of economic impact results that incorporate the uncertainties in the entire fate and transport modeling sequence. These results address parametric uncertainty in the models. If one or more alternate conceptual models were incorporated in the modeling steps, the results can be used as a partial indicator of conceptual model uncertainty. Integration of the risk elements will incorporate uncertainty in the information passed between elements.

Uncertainty regarding costs, revenues, and nonmonetary values will be accounted for by incorporating information on variation in these measures with regard to time, space, and resource quality. To the extent possible, uncertainties will be analyzed using readily available local data. For example, some local data are available on links between irrigated agriculture and the rest of the local economy so that economic impacts of proscribed water supplies to agriculture could be estimated relatively easily. Ranges of values for product prices, production, water use and economic linkages needed to evaluate uncertainties are available for irrigated agriculture.

F.3.3.3 Assumptions/Technical Rationale for the Economic Impact Conceptual Model. Information is needed as a basis for projecting the extent and duration of avoiding any product or activity in response to information regarding health risks. It is assumed that such estimates will be developed for each product, activity, or business type that is likely to be affected by the health and ecological risks assessed in SAC (Rev. 0).

It is assumed that changes in local product markets or activities do not affect national price levels for these products or activities. This may be a strong assumption for some narrowly-defined categories of agricultural products if the impact region produces a major share of product supply, such as possibly hops or mint, or if the resource is unique within the region, such as possibly windsurfing activity in the Columbia Gorge.

Current economic conditions are assumed to represent the baseline conditions at the time of site closure. The year 2050 will be treated as the base year of the economic analysis.

F.3.4 Social, Cultural, and Quality of Life Conceptual Model

This section provides the details on the proposed social, cultural, and quality of life conceptual model. Based on the generalized risk and impact conceptual model (Figure F-1), socio-cultural impacts can arise in ways similar to economic impacts discussed in Section F.3.3. Impacts can occur directly from the presence of contamination, or indirectly through ecological or human health impacts that affect the use of the resource for social or cultural use. Also, related economic impacts can affect the social, cultural, and quality of life impacts.

A socio-cultural component has been added to the SAC because of a growing recognition that the conventional risk assessment paradigm does not address all of the things that are “at risk” in communities facing the prospect of contaminated waste sites or permitted chemical or radioactive releases. Communities may experience adverse effects in the health of their social and cultural systems in addition to the more easily recognized human health and local ecological health effects. Although they may vary in specifics and intensity, all cultures share the same general quality of life indicators, such as community and individual wellbeing, spirituality, concern for future generations, peace of mind, resource access and use, and sustainability of the worldview. The presence of residual contamination could have a negative impact on social, cultural, or religious activities that occur in a particular place or require particular natural resources. This could affect the ability to take children to particular places to learn about their heritage or about environmental functions. It could affect environmental qualities that the community identifies with or relies on for recreation, income, aesthetic enjoyment, and so on. Finally, effects on individual health, community exposure burdens, and environmental functions can combine to affect the quality of life of an individual and the community.

John M. Last (1998) defines health as “a state characterized by anatomic integrity, ability to perform in a manner consistent with values as a person and in family, work, and community roles; ability to deal with physical, biological, and social stress; a feeling of wellbeing; and freedom from the risk of disease and untimely death”. This definition does not specifically call out the fact that the survival and wellbeing of every individual and culture depends on a healthy environment. Indeed, indigenous people and their environs are intertwined to a degree that is usually not accounted for by western society and scientists. The environment constitutes a cultural homeland where the people (and their genetics) co-evolved with the ecology over thousands of years. Additionally, before the start of nuclear weapons production in the early 1940s, the Hanford Site was the home to nonindigenous American farmers. They were removed when the land was taken over for plutonium production.

The level and scope of social assessment needed depends on the particular context of specific health or environmental risk considerations and the potentially affected communities and activities. Stakeholders and communities affected by remediation program decisions will vary for different potential impact zones associated with each risk scenario. Thus, for each plausible scenario of health or environmental risk, a zone of impact needs to be identified for evaluation. Table F-9 provides an example of how the impact zones and stakeholders might be characterized.

Table F-9. Potential Impact Zone Definitions and Stakeholders from DOE-CRE 1999.

Potential Impact Zones	**Major Stakeholders**
Onsite area, including groundwater	Privatization enterprises, federal government, local business and industry, groundwater users, agriculturists, tribal governments, Washington state government, city and county governments.
Columbia River, Benton/Franklin County (Tri-Cities, etc.) and region upstream from the McNary Dam	Local business and industry, including agriculture, fisheries, manufacturing, recreation; community residential water agencies; tribal governments; Washington and Oregon state government, city and county governments.
Columbia River, downstream from the McNary Dam	River basin region business and industry, including agriculture, fisheries, manufacturing, recreation; community residential water agencies; tribal governments; Washington and Oregon state government, city and county governments.

The evaluation of cultural risk includes evaluating the probability of impacts to community quality of life, to the ability to follow traditional lifeways, to historical and cultural artifacts and landscapes, to human exposure as cultural and other activity patterns are pursued, and to the health and functionality of the surrounding environment. The health and ecological risk findings are not the endpoint in the quality of life evaluation, but provide essential information to the process. Clearly, an exposure causing a potentially unacceptable risk to a resource or from an important resource to its users could negatively impact the quality of life. However, even if, by scientific or regulatory definitions, there is no human health or ecological risk, the patterns of life could be disrupted to the point that the culture is harmed.

The following are routes or mechanisms of social or cultural harm:

- Impaired socio-cultural quality of the resource or area due to ecological contamination above or below a regulatory or risk-based standard (a direct effect).
- Socio-cultural impacts from ecological harm.
- Socio-cultural impacts from health risk or exposure above **or below** a regulatory standard.
- Socio-cultural impacts due to avoidance or proscription of access/use in order to reduce human exposure.
- Socio-cultural impacts due to response to a remediation action (for example, excavation).
- Socio-cultural impacts due to **costs** of response, avoidance, proscription (lost services), or restoration.

Several types of information must be gathered in order to do a comprehensive socio-cultural impacts analysis:

- The social and cultural characteristics of the community or subpopulations, and the resource access and usage patterns of the community before Hanford Site operations.
- Co-risk factors or reasons why the health, cultural way of life, values, or natural resource infrastructure of each group may already be at risk or may be at higher risk.
- How those resource usage patterns and the overall social environment and community health systems would change in response to the range of stimuli associated with the remediation program alternatives.
- Selection and evaluation of risk measures relating to social quality of life, cultural activities, access and use to the site or resource, risk to cultural or historic resources or landscapes, equity, and so on.

General types of measures associated with a comprehensive analysis are shown in Table F-10.

Table F-10. Example Social, Cultural, and Quality of Life Measures.

Direct cultural harm related to natural and cultural resource effects: • Number of plant and animal species harmed or contaminated, weighted by socio-cultural importance (T&E, Trust resource, etc.). • Number of sites, historical buildings, etc. harmed or contaminated, × weighting (importance). • Number of contaminated sub-locations within total area above background or detection limit important for social, educational, recreational, religious, or other reasons. • Ecological functional/integrity index relative to original condition × duration of harm × area (service-acre-years). • Percent of original landscape, viewshed, soundscape remaining in original condition × duration of impact.
Impairment of socio-cultural quality or use due to contamination above background or detection limit (acres/river miles/soil mass/gallons/curies × time)
Social/Cultural effects due to restricted access (degree of restriction × time)
Social/Cultural effects due to number of sustainable future use options lost, lost trust or peace of mind (H-M-L scale), proximity of contamination to other resources/areas.
Social/Cultural effects due to human exposure or health effects in subpopulations.
Social/Cultural effects due to economic effects and response costs
Proportion of target cultural or social group affected by harm to the area or resource

For human health impacts (Section F.2) the cancer metric (incremental lifetime cancer risk) is quantitatively well defined and benchmark values indicate the severity of the risk. For example, a risk below 10^{-6} is considered to not pose a significant impact to an individual or population. However, for socio-cultural impacts, although they may appear to be quantitative (for example, the acreage of ground water with contamination above background), the scale of severity is not well defined. Within each category of measures mentioned in Table F-9, the following characteristics or attributes provide a means to qualitatively assess the severity of the impact:

- **Likelihood**: Probability of occurrence or adverse effect; cumulative probabilities.
- **Magnitude**: Severity, with degree of secondary effects.
- **Sensitivity**: Number and significance of co-stressors or co-risk factors or vulnerability.
- **Duration** of exposure and/or impacts and persistence in the body or environment.
- **Quantity**: Numbers of people or acres or species.

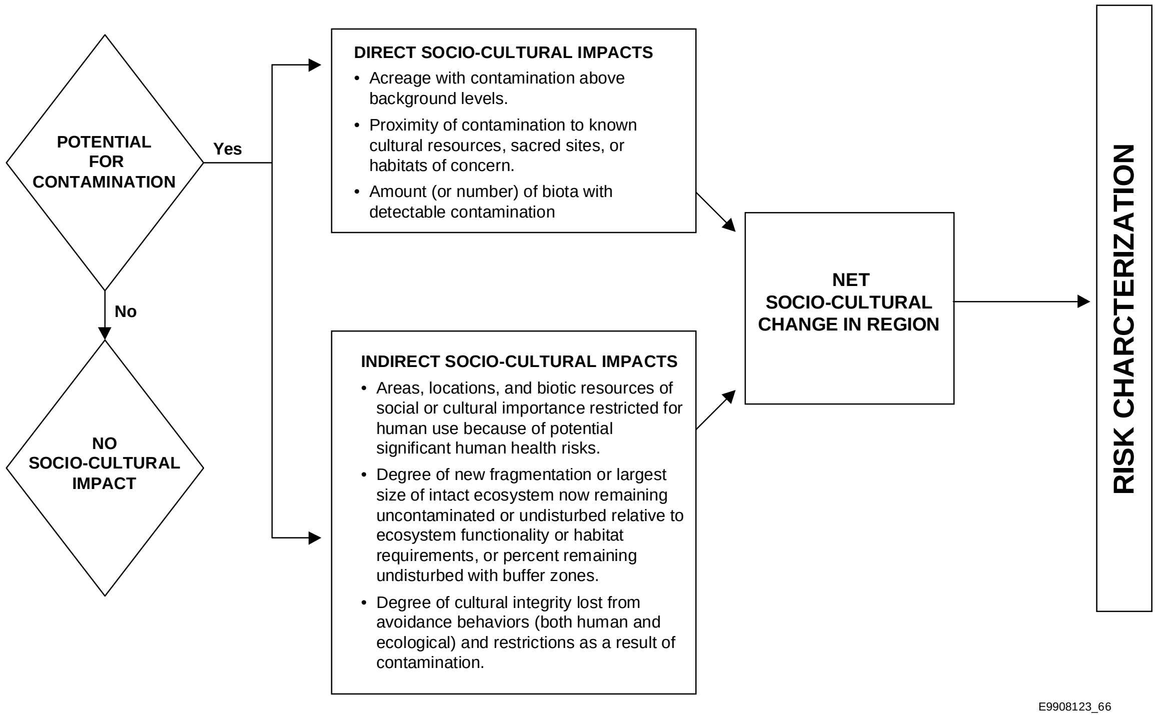
- **Proportionality**: Proportion of resource or group affected.
- **Distribution**: Distribution of impacts among the people or species or ecosystems, or distribution of hotspots in the landscape, or degree of clustering/nonhomogeneity.
- **Time**: To impact or time to initiating event.
- **Equitability**: Is the impact or cost to one group larger than to another? Is the proportion of one affected group larger than another? Are the resources of more value to one group than to another?
- **Confidence**: a qualitative or quantitative measure of uncertainty that cultural impacts cannot be determined for individual contaminants. Transport modeling done for individual contaminants must be combined with scaling factors for additional co-migrating contaminants. Some metrics are based on the presence of any contaminants, whether they are toxic in the conventional sense or not. Further, cultural effects are both point-located (if a particular resource is affected, but no other area is affected), and area-wide. Some acre-year metrics cannot be determined by summing impacts at individual points, but must be calculated by knowing acreages and isopleths first where all/any contamination occurs, then applying the metric to the entire area.

F.3.4.1 Social, Cultural, and Quality of Life Conceptual Model for SAC (Rev. 0). For the present analysis, which predominantly has a natural resource focus, the cultural communities or subpopulations may be defined by their relation to their places and resources. Since tribal cultures make use of natural resources of the Hanford Site, the cultural impacts to tribal resources and impacts will be the focal point of the analysis for SAC (Rev. 0).

The socio-cultural assessment must make use of surrogates for cultural values in terms of the presence of a socially or culturally important resource at a location. For example, the presence of salmon spawning areas in the Columbia Reach can be used as a surrogate for the viability of the Native American culture and way of life that relies heavily on the presence of salmon. Any Hanford Site contamination that could potentially impact the sustainability of the spawning areas could have an adverse effect on a key resource for the culture's survival.

Therefore, an important aspect of defining the social and cultural impacts of contamination is to relate areas of contamination to the location of the resources (Figure F-13). The SAC (Rev. 0) will focus on relating the locations of contamination, currently and in the future, to the locations of socially and culturally important resources, such as the salmon spawning areas, water withdrawal points, and culturally sensitive areas. This will be the first attempt to provide basic information to describe qualitatively the potential impacts of Hanford Site contamination on socially and culturally sensitive resources.

Figure F-13. Socio-Cultural Conceptual Model for SAC (Rev. 0).



The metrics for the socio-cultural assessment for SAC (Rev. 0) are given in Table F-11.

Table F-11. Socio-Cultural Impacts and Metrics for SAC (Rev.0).

Impact	Metric
Direct effects of contamination on resources of socio-cultural importance	Acreage (of soil, soil underlain by groundwater) with contamination above background levels. Proximity of contamination to known cultural resources, sacred sites, or habitats of concern. Amount (or number) of biota (ecosystem level and species) with detectable contamination.
Indirect effects of contamination resulting from human health, ecological or economic impacts	Areas, locations, and biotic resources of social or cultural importance restricted for human use because of potential significant human health risks. Degree of new fragmentation or largest size of intact ecosystem now remaining uncontaminated or undisturbed relative to ecosystem functionality or habitat requirements, or percent remaining undisturbed with buffer zones. Degree of cultural integrity lost from avoidance behaviors (both human and ecological) and restrictions as a result of contamination.

F.3.4.2 Dealing with Uncertainty in the Socio-Cultural Conceptual Model. The application of social and cultural ideas in risk assessment is an emerging discipline. It is increasingly recognized that there can be impacts to society and its culture in general, and to specific minority groups in particular, as a result of the presence of environmental contamination. However, there is not a universally recognized definition of a social or cultural impact, akin to an increased risk of cancer for a human health exposure to contamination. Nor is there a clearly defined relationship between levels of contamination and degree of social or cultural harm. As a result, the approach to estimating social and cultural impacts for the SAC relies heavily on the surrogate of the location of contamination in the proximity to resources of concern. Therefore, it is appropriate to deal with uncertainty in the assessment of cultural impacts and risks in a qualitative (descriptive) manner. An example approach is outlined in Appendix G (Section G.4.2).

F.3.4.3 Assumptions/Technical Rationale for the Socio-Cultural Conceptual Model. The major assumption for the socio-cultural analysis is that the present configuration of natural resources will remain the same for the future. No attempt will be made to predict changes in the type and location of natural and cultural resources as a result of natural processes or human activities.

F.4 ASSUMPTIONS/TECHNICAL RATIONALE FOR THE SAC (REV O) RISK AND IMPACT CONCEPTUAL MODEL

The assumptions and technical rationale for each risk element proposed for SAC (Rev. 0) was discussed in Section F.3. The integration of the risk elements will involve further assumptions.

F.5 WHAT THE SAC (REV. 0) CONCEPTUAL MODEL IS DESIGNED TO ANALYZE

A greater range of risks and impacts is included in the design of the conceptual model for SAC (Rev. 0) than have been conducted on the Hanford Site to date.

F.5.1 Ecological Risk

The conceptual model for ecological risk provides the basic elements necessary to estimate whether COPCs entering the river have a significant probability of producing adverse effects on the biological resources of the Columbia River within the SAC (Rev. 0) study area, that is, the Hanford Reach to McNary Dam. Biological resources included in this conceptual model are those that have been defined in the Rev. 0 study set; adverse effects to be evaluated are also defined in the SAC (Rev. 0) study set for the risk module.

Ecological risk will be evaluated by quantitatively assessing the effects of a limited set of COPCs on selected aquatic and terrestrial species. The conceptual model anticipates that there will be a qualitative characterization of the concerns that are not included in the quantitative exercise.

F.5.2 Human Health Risk

The human health risk conceptual model is designed to evaluate the scenario URF based on the pathways and occupancy (usage) factor. The calculated URF would convert the media concentration into cancer risk for carcinogenic chemicals using the EPA slope factor. Toxic effects from exposure to noncarcinogenic chemicals will be evaluated in terms of a hazard index.

The SAC (Rev. 0) is designed to analyze the incremental life time cancer for the carcinogenic chemical and radionuclide. For the non carcinogenic chemicals, the system impacts are respiratory, cardiovascular, gastrointestinal, hematological, hexatin, musculoskeletal, and renal.

F.5.3 Economic Impacts

The focus of the conceptual model is on quantifying economic impacts of actions that are likely to be taken to avoid human health risks. This involves characterizing the nature and extent of likely actions in relation to various types and levels of health risks. It also requires quantifying both monetary and nonmonetary impacts resulting from changes in perceptions and behaviors associated with affected resources or activities. The model is designed to identify the distribution of these impacts among economic sectors, population subgroups, or subregions of the impact area.

F.5.4 Socio-Cultural Impacts

The selection of the metrics for the social, cultural, and quality of life conceptual model depends on which communities of sub-populations are affected the most or value the area and its attributes or resources the most. Based on the fact that the Tribes have certain treaty rights at Hanford and are closely associated with the natural resources of the area impacts to tribal cultures will be the focus of the SAC (Rev. 0) cultural assessment.

F.6 WHAT THE SAC (REV. 0) CONCEPTUAL MODEL IS NOT DESIGNED TO ANALYZE

The conceptual model is focused on a post-closure assessment. Analyses related to the operation of the Hanford Site or the ongoing cleanup effort are not included in the design on the conceptual model. For example, analyses of risks and impacts in the central plateau of the Hanford Site is limited to use of groundwater by humans. Therefore, the conceptual model does not include the features, events, and processes necessary to evaluate ecological or cultural impacts to sagebrush habitat. In addition, occupational risks are not included since these risks would not be associated with Hanford when the site is closed.

F.6.1 Ecological Risk

The conceptual model does not address ecological effects outside the SAC (Rev. 0) study set boundaries, including spatial area, temporal scope, impacts, and receptors.

F.6.2 Human Health Risk

An intruder scenario is not analyzed. Also, occupational risks are not included. These assessments are performed as part of the site-specific assessments.

F.6.3 Economic Impacts

Events outside of the set boundaries of the SAC (Rev. 0) spatial, temporal, or impact study are not addressed. The SAC (Rev. 0) does not analyze impacts of ecological risks or the economic impacts of human health effects. Human health effects are accounted for without assigning monetary values.

Within a spatially-isolated economy like the Tri-Cities, impacts on individual sectors tend to cause repercussions throughout the web of economic relationships. The conceptual model does not account for these indirect impacts in SAC (Rev. 0), except perhaps in a preliminary fashion. These will mainly be addressed in future development of the risk assessment capability.

F.6.4 Socio-Cultural Impacts

Socio-cultural resources outside the study area (the Hanford Reach to McNary Dam) will not be addressed in SAC (Rev. 0).

F.7 OUTSTANDING ISSUES

Understanding the relationship between the risk elements remains an outstanding issue. The process of integrating the risk elements has yet to be completed. More integration will be apparent as the design of the analysis for SAC (Rev. 0) gets closer to completion. Additional iterations of the SAC will provide further integration.

F.7.1 Ecological Risk

Effects on ecological attributes such as rate of population growth, sustainable harvest, yield, community stability, biodiversity, or habitat suitability are not directly assessed. Ecological effects are addressed directly at the level of the exposed individual; higher-order effects are covered by implication. In this approach, effects on attributes of individuals implicate effects at higher levels of organization, such as changes in population abundance or probabilities of extinction. This approach is conservative in that higher-order effects do not follow inevitably from effects on lower-order properties, but higher-order effects cannot arise without effects on lower levels of organization. If the degree of conservatism is found to be unacceptably high, research will be required to either develop dose-response curves for higher-order impact metrics, or develop the capability to use lower-order effect levels to reliably predict effects at other levels of organization.

Toxicity data are seldom available for species other than those amenable to laboratory study. The following approaches are available to extrapolate from these species to those in the Rev. 0 study set:

- Matching SAC (Rev. 0) species with laboratory species as near as possible on the basis of taxonomic relationships. This approach is based on the assumption that taxonomically similar species will respond similarly to COPCs.

- Using the lowest reported benchmark value for all SAC (Rev. 0) species independent of the species relationships. This approach is considered to be conservative, but will generally overestimate risk.

- Using a predetermined percentile of all similar benchmarks among all tested species as the benchmark for the Rev. 0 species. This approach is used by EPA to set ambient water quality criteria, which are based on 5th percentiles of LOAELs. This approach also assumes that the Rev. 0 species response is represented by the 95th percentile of laboratory species, and may be overly conservative.

- Comparing the distribution of laboratory-derived benchmarks to the distribution of estimated exposures for SAC (Rev. 0) species under a single exposure scenario. This provides an estimate of risk that accounts for the possibility that the SAC (Rev. 0) species response could fall anywhere within the range of benchmarks from laboratory species. This approach will be used in the SAC (Rev. 0) conceptual model.

F.7.2 Human Health Risk

The conceptual model for human health risk primarily presents deterministic risk. The stochastic risk assessment needs to be defined and depends on the SAC computational model selection. Deterministic risk will be based on the estimated concentrations, such as maximum, average, and best-estimate concentrations.

F.7.3 Economic Impacts

Estimates are needed for the behavioral changes (for example, in resource use) that are likely to occur in response to various health and ecological risks. In the risk assessment context, methods for projecting behavioral changes are not well developed or standardized since impacts due to changes in risk perceptions are not included in the scope of NEPA documents. This exclusion is based on the court ruling in the PANE case (Metropolitan Edison Company v. People Against Nuclear Energy 1983). There is, however, considerable guidance available in the economic literature for performing many of the required analyses, and some guidance from Federal agencies such as the National Marine Fisheries Service (contingent valuation), the Army Corps of Engineers (economic accounts and procedures for estimating net national and regional economic benefits), the Council on Environmental Quality (for analysis practices related to environmental statements), and the U.S. Nuclear Regulatory Commission (calculation of benefits and costs and their use in environmental impact statements).

F.7.4 Socio-Cultural Impacts

The use of surrogates for social and cultural impacts (co-location of contamination and resources) may not adequately represent the complexity of the concerns of Tribal Nations and other stakeholders. More consultation and information may be needed to adequately address their concerns.

F.8 PROPOSED PATH FORWARD

The proposed path forward for the SAC (Rev. 0) risk and impacts conceptual model includes:

- Integrating the risk elements.
- Capturing the issues in conducting the risk assessments and impact predictions in dependency webs, demonstrating the components of the conceptual model, and the relationships between the risk elements.
- Analyzing the metrics proposed for SAC, Rev. 0, (Table F-12).
- Describing additional metrics through the risk characterization process as necessitated by limited information or scope of study.
- Telling the story of risks and impacts of assessing the cumulative health and environmental effects of the Hanford Site contaminants on the ecology, human health, economics, and culture of the affected area. This will be accomplished through the risk characterization process.

F.8.1 Ecological Risk

The conceptual exposure model must be converted into an equilibrium quantitative model that should incorporate stochastic input. The ECEM code provides the necessary capabilities for implementing this conceptual model. Parameters needed for the model will be collected from existing compilations (e.g., DOE 1998a), Hanford research, and the open literature. Uncertain parameters may be estimated where possible using a consensus approach of regional biologists. ECEM will produce a body burden that can be translated to effects of dose and/or risk, as appropriate.

Ecological risk will be evaluated by quantitatively assessing the effects of a limited set of COPC on selected aquatic and terrestrial species. The effects conceptual model compares the estimated distribution of exposure for each SAC (Rev. 0) species at each exposure site to the toxicity-response distribution for that species and COPC (see the section on Outstanding Issues for additional discussion on this point). This approach, a variation on the quotient method (EPA 1996), will provide an estimate of the cancer and noncancer risk of exceeding a toxicological threshold. Noncancer estimates will be summed by mode of action.

Table F-12. Summary of Impacts and Metrics for SAC (Rev. 0).

Impact	Metric
Ecological	
Impact	**Metric**
Key Individual Species	Lowest Observed Adverse Effect Level (LOAEL) for toxicity of individual COPC (chemicals/radionuclides) to an individual receptor.
Ecosystem	Food web for aquatic and riparian ecosystem. Ecosystem structure and function.
Human Health	
Impact	**Metric**
Incremental Lifetime Cancer Risk	Additive single pathway and multiple pathway cancer risk for all carcinogenic COPC (risks from radionuclides presented separately from those other for other carcinogenic COPC).
Non-cancer, e.g., respiratory, cardiovascular, gastrointestinal, hematological, hepatic, musculoskeletal, renal, and others	COPC-specific, multiple pathway hazard indexes, segregated hazard indexes for COPC with similar mechanism/mode of action or affecting the same organ system.
Economics	
Impact	**Metric**
Proscription/Public avoidance of products	Changes in quantity sold and revenues; effects on workforce.
Proscription/Public avoidance of recreational activities	Change in recreation value.
Alternative water supply cost	Changes in costs (other sources).
Loss of business recruiting options	Changes in net income, employment; loss in tax base.
Socio-Cultural	
Impact	**Metric**
Direct effects of contamination on resources of socio-cultural importance	Acreage (of soil, soil underlain by groundwater) with contamination above background levels. Proximity of contamination to known cultural resources, sacred sites, or habitats of concern. Amount (or number) of biota (ecosystem level and species) with detectable contamination.
Indirect effects of contamination resulting from human health, ecological or economic impacts	Areas, locations, and biotic resources of social or cultural importance restricted for human use because of potential significant human health risks. Degree of new fragmentation or largest size of intact ecosystem now remaining uncontaminated or undisturbed relative to ecosystem functionality or habitat requirements, or percent remaining undisturbed with buffer zones. Degree of cultural integrity lost from avoidance behaviors (both human and ecological) and restrictions as a result of contamination.

In addition, the conceptual model anticipates a qualitative characterization of the concerns that are not included in the quantitative exercise.

F.8.2 Human Health Risk

The path forward for deterministic human health risk is to generate the URFs for the COPC and compare them to those URFs documented in the TWRS-EIS and CRCIA.

F.8.3 Economic Impact

An effort is required to develop parameter estimates for the generation of trigger-mechanism scenarios.

F.8.4 Socio-Cultural Risk

The near term focus will be on obtaining feedback on the completeness of the socially and culturally significant resources of concern for comparison to the locations of present and likely future contamination. This will require close linkages among the socio-cultural metrics with the locations and habitats of concern from an ecological, human health and economic perspective. The interaction among the four risk types will help ensure that the relevant concerns from the use of a particular resource, such as salmon**,** will be addressed in a more complete fashion than in the past.

F.9 REFERENCES

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